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WORLD PETROLEUM

FEBRUARY 1939

NEW YORK AND LONDON

LIMA'S THREAT

EFFECTIVE PRORATION

WORLD OUTPUT DOWN

COASTLINE OWNERSHIP

U. S. OIL EXPORTS

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RUSSELL PALMER
Publisher

E. W. Mayo
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T. Orchard Lisle
Executive Editor

E. W. Mayo, Jr.
Managing Editor

S. J. Gallay
Advertising Manager

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CORRESPONDENCE

ADDRESS all correspondence regarding subscription and business matters to the Home Office; 95 River Street, Hoboken, N. J.

Editorial and Advertising offices; 56 West 45th Street, New York, N. Y.
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(Above) Work goes on in the Signal Hill field, California—photo by Cy. La Tour. Front cover illustration shows wells on the Ford Motor Company's property at Wilmington, California—photo by Inman.

E D I T O R I A L

SERVING AN OIL CONSCIOUS WORLD

IT WILL be many years of course before the rest of the world catches up with the United States in the extent of its petroleum activities. More than sixty percent of the total annual production of oil is still accounted for by this country. A study of existing trends provides strong evidence however, that from this time on the relative share of other lands in supplying the world demand for petroleum products will become more and more important.

There are obvious reasons for this change which has begun to make itself felt to a growing extent during the past three or four years. First of all the world at large has become increasingly oil conscious. It is realized that petroleum products are an absolute essential to progress in peace and to success in war. As a measure of defense every nation is striving to assure itself of direct control or certain access to supplies adequate to provision its war machines and to maintain the transport systems without which modern armies are helpless.

Many countries which had long remained indifferent to the movement toward modern industrialization are now responding to its call. Diesel engines are performing the humble tasks that for ages have been relegated to human or animal power. Motor cars roll over modern highways where once only camel caravans passed. Airplanes wing their way across untrodden wildernesses. During the past few years the demand for petroleum products has shown a more rapid rate of gain in the world at large than in the United States. This trend is likely to continue because other countries have much further to go than the United States which already is far along on the road to complete motorization.

All these developments are working great changes. They have started the most extensive, systematic and scientific search ever undertaken to locate undiscovered deposits of petroleum. This movement is well under way. It is concentrated in three great segments of the earth's surface, South America, the Near East, and the Far East, simply because these include the greatest areas of unexplored territory, but it extends to every corner of the globe from Alaska to New Zealand. The great explorers of the present day are members of geophysical crews. Tool pushers and wielders of the welding torch speak as familiarly of Baghdad and Palembang as they do of Beaumont or Bakersfield.

Great changes in business are attending this transition. The opening of new oil fields demands not only men but machinery of every sort. The export of oil field, pipeline and refinery equipment from the manufacturing centres of the United States and Europe is growing in tremendous strides. The sales manager who until lately gave grudging attention to a foreign order now sends his best salesmen around the world to snare this business. The export manager who once cowered behind his one desk in a corner of the sales department now rules over a well staffed suite in a modern skyscraper and commands respectful attention when he presents his views to the executive committee.

Whatever may be the record of 1939 in other respects it is certain to surpass all its predecessors in the volume of activity taking place in the oil industry outside the United States. The amount to be expended on geophysical surveys is staggering in its aggregate. Thousands of test wells and other thousands of anticipated producers are to be drilled. Pipe lines are projected through jungles and across deserts. Engineers are busy with plans for refineries in both hemispheres. The oil industry may be forced to mark time here and there waiting for demand to catch up with the drill, but in the large view that embraces its world wide activities it is entering upon one of its busiest years.

LIMA'S THREAT to the United States

By Henry J. Allen

BROODING over the Pan-American conference at Lima was the shadow of oil confiscations. The best that can be said of the result of the conference, so far as the oil situation is concerned, is that it did not further complicate matters.

Students of the situation knew that Mexico would try to get written into the good neighbor policy an exculpation of her action in confiscating oil and other properties and that before the Congress ended some new international philosophy would be put forward placing confiscation upon a respectable basis. Although attention centered upon Mexico's confiscations, Bolivia had seized United States oil properties a year earlier. And it was no secret that among those gathered at Lima were others who would welcome a public justification of such a policy.

Three separate and distinct attempts were made to endow the good neighbor policy as a license to steal. Fortunately for everybody, the efforts failed. It was known that Mexico and Bolivia were both quietly behind these plans, although they did not appear openly except as supporters of them.

The first effort to write some new international law in justification of confiscations occurred when a Chilean delegate brought in a resolution, which if accepted, would make local law supreme over international law.

It was a plain effort, when interpreted into a common understanding, to set up an international provision that the United States to satisfy any pecuniary obligation, debt or confiscation, must go into the local court of the government which was guilty of confiscations.

In two outstanding instances recently, the futility of depending upon local courts has been emphasized. In Mexico, the constitution has been changed to provide that the tenures of supreme court justices shall run current with the term of the president, thus making the members of the court political puppets of the administration in power. In Bolivia, prior to the confiscation of the oil wells, precisely the same thing was done.

The proposed amendment of the Chilean delegate created rather a profound impression in the Conference, but nobody talked loudly about it. The campaign for and against it was largely in whispers. Chile pretended a great enthusiasm for the resolution. Mexican and Bolivan delegates. backed up the Chilean eloquence.

Nevertheless a feeling of relief ran through the congress when it was finally announced that the committee on international law, into which this effort was introduced, had voted to refer the proposed amendment to the committee of experts. This meant that this particular amendment cannot come up again until the next conference, which convenes in five years.

After a breathing spell of some 48 hours, the second scheme to hamstring the United States in any attempt to collect an international obligation, was sprung. It was much less direct but more deadly than the Chilean resolution.

This second resolution was introduced by Mexico, supported by Chile. In it, Mexico tried to put across the old Calvo doctrine with a new twist, in spite of the long series of objections by the United States. She also introduced into a good neighbor resolution the provision that no intervention, by force or diplomacy, should be used by a creditor nation for the collection of a pecuniary claim which involved bonded debts, contractural obligations, et cetera.

Argentina backed a resolution to take away from all foreign corporations doing business in Latin states, their nationality. In other words, the large United States corporations owning mines, transportation companies, oil companies, or incorporated property of any kind, were to be rendered stateless and would be left wholly to the authority of whatever republic they had chosen to endow with their investments. It was cunningly phrased. It sounded like an unimportant amendment to an international compact, because it was saying in eloquent language that the good neighbor policy had now progressed to a point where the protection of international charters was not needed in Latin America. It was setting up the doctrine that every American republic had reached a point where its own power over corporate charter was ample protection to any foreign corporation.

It was probably, in its comprehensive possibilities, the most threatening move attempted at the conference. It would have rendered every dollar of capital invested by United States citizens in any other American state dependent upon whatever courts, under whatever laws the politicians in those states deemed wise for any desired accomplishment at any moment.

Finally a profound shock occurred when the first draft of the Lima Statement, which was to be the big work of the conference, showed that the friends of confiscation were still busy.

The Lima Statement was to express the first all-American compact against the subversive revolutionary influences of Europe. It wasn't expected, therefore, that it would contain any echo of what had been going on for fourteen days in the fruitless effort to make confiscation fairly secure. The last surprise came when Argentina wanted it written into the concord that "we will present a united front against any American state which violates this principle or menaces by the use or threat of force, the peace, security or territorial integrity of another American state."

The proposal elaborated by adding that "in the event that the peace of any American state is menaced from within the continent by the direct or indirect interference of another state or by unofficial acts or activities which have support from another state which may change or subvert the national or political institution of the threatened state, consultation shall always be instituted exclusively by the government of the threatened state."

The proposed article did not go through, but the fight for it consumed many hours. Its significance should not be overlooked by those officials whose duty it is to see that the good neighbor policy does not become a racket with the United States as its exclusive victim.

This warning is justified by the more recent developments in Mexico where the business of trading stolen oil to Germany in return for German goods goes on with renewed activity. It now appears that Mexico is setting up a German trading post. She trades confiscated oil to Germany at a marked-down price. Because of this, Germany can sell her goods to Mexico on a scale which defies all competition. It is little wonder that other Latin American states now appear ready to buy from Mexico some of the goods which she receives from Germany in return for the stolen oil.

The further development of this clearing station will probably be rapid since it is understood that the special mission upon which General Juan F. Azcarate recently rushed post-haste to Germany, has to do with the oil barter. The set-up appears to be forming for Mexico to become the middleman and agent of the Nazi power in its program for large scale trade invasion of the western hemisphere.

DESIGN FOR More Effective PRORATION*

By **Joseph E. Pogue,** Vice President, The Chase National Bank of the City of New York

PRORATION literally means the allocation of demand among competing producers on a pro rata basis, but the term now carries a much broader significance for it is employed to describe the entire process by which the production of crude oil in the United States is regulated. There is naturally much confusion of thought on the subject, for proration is an evolving system of control based upon principles of conservation and equity and embracing a body of practices that are tending to adjust themselves to the needs of the situation but are subjected to varying and divergent influences in the process. As it is now constituted, proration is a planned production measure designed to prevent waste, insure ratable takings, and balance supply and demand. The procedure is administered by State regulatory bodies through use of the police power of the States under authority of State conservation laws; the practice is supported by a considerable degree of voluntary conformance on the part of operators; and the Federal Government has accorded its cooperation by providing advisory quotas, circumscribing imports, checking movements of hot oil in interstate commerce, and ratifying an Interstate Oil Compact. In the course of the past 12 years, this regulatory system has become an institution with a framework of laws, court decisions, administrative bodies, committees, trade practices, and traditions.

In a limited form, proration made its appearance at various times in the past where flush production outran the absorptive powers of the market, but was abandoned in each case as soon as supply subsided so that equilibrium could be resumed without its aid. Within the past 12 years, however, the improved technical ability to find oilfields coupled with a slackening in the growth-rate of demand, has built up a productive capacity so far in excess of market requirements that proration, invoked as an emergency measure, has become a permanent establishment. There are two reasons why the conjuncture of advancing technology and maturing demand led to the institutionalization of proration: the rule of capture created an urge to produce that could not be readily restrained by the regulatory effect of price; and the tremendous difference in out-of-pocket costs between flush production and settled production transmuted this impulse into violent price changes of disturbing influence upon the economy. In consequence, once launched in the new technologic setting, proration appeared indispensable as an operating form and in turn generated the need for its spread and implementation. In short, the rule of capture became unworkable under modern technologic conditions, and proration developed as an offsetting and naturalizing influence.

Although initiated to correct conditions of overproduction, proration has its justification as a fundamental conservation measure, and its development centers around that theme. The practice of proration has clearly demonstrated that restricted flow of oil wells conserves the reservoir energy, and results in higher recoveries and lower over-the-life costs than experienced if wells are produced under conditions of open flow. The advantages of delayed production are now well understood, but these gains are not attainable under the competitive operation of leases in subdivided oil pools. Only by actual pooling of leases in the single reservoir, unit operation—or by the imposition of rules of production that comes to the same effect, proration—can the oil pool be handled according to the dictates of advanced engineering practices. Consequently, a curtailment of flush production promotes recovery and operating efficiency while leading to improved economic balance.

CONSERVATION

The ideal way to produce an oilfield is to restrict the flow to a rate that results in the most effective utilization of the reservoir energy. In this manner the greatest practicable recovery of the oil is achieved and resort to pumping is deferred until near-exhaustion of the deposit. The form of the reservoir energy is complex, varying from pool to pool, but in general it is represented by the driving power of edge and bottom water under hydrostatic pressure and by the compressed gas associated with the oil. The energy inherent in the gas manifests itself as a propelling force upon the release of pressure, and the dissolved gas renders the oil more fluid and reduces its tendency to stick to the sand grains. Fortunately the full effects of water drive and gas can be utilized by adjusting the flow to the most efficient, or optimum, rate, which is subject to more or less exact determination if sufficient engineering effort is devoted to the matter.

In the subdivided pool, which is the prevalent type, an additional procedure is necessary; namely, rates of withdrawal from the several properties in proportion to the available oil underlying each. This qualification is essential on two counts: first, to maintain the reservoir energy in continuing equilibrium in order to support optimum recovery; and second, to preserve equity as between the competing property owners. If the reservoir energy is not held in equilibrium but important differentials are permitted to develop in the reservoir as a result of unbalanced withdrawals, optimum recovery is unattainable and each operator must resort to the rule of capture to preserve his equity.

Conservation of oil, accordingly, can be attained by any system of operations that restrains the flow of the oil pool to the most efficient rate and enforces ratable takings among the competing operators in the pool. The determination of the optimum rate and of the ratable-takings formula is primarily an engineering problem. The objective is to deal with the reservoir energy, rather than the oil itself, but there are two schools of thought as to the best utilization of the reservoir pressure: the one regards it as a force to be spent, so much for each unit of production; the other, as a force to be conserved until virtual exhaustion of the oil. Upon further engineering research, the latter point of view will probably be found to be preferable, at least in all fields where a water drive can be utilized, for substantial pressure drops tend to induce a nonuniform encroachment of the water and, in gas-saturated pools, permit gas to come out of solution to the detriment of ultimate oil recovery.

Conservation as here defined was not attainable during the period of rapid growth in the industry, for then open-flow operations, even under the stimulus of the rule of capture, were required to meet the mounting demand. Curtailed flow, the essence of conservation, became possible only after a large potential supply of oil had been made available. Hence it was inevitable that an excess of capacity must develop before demand could be filled by production throttled down to an efficient rate. Thus in the evolution of the industry, the transition from open flow to conservation practices had to be in a setting of

*Paper delivered before the A.I.M.M.E., New York, February, 1939.

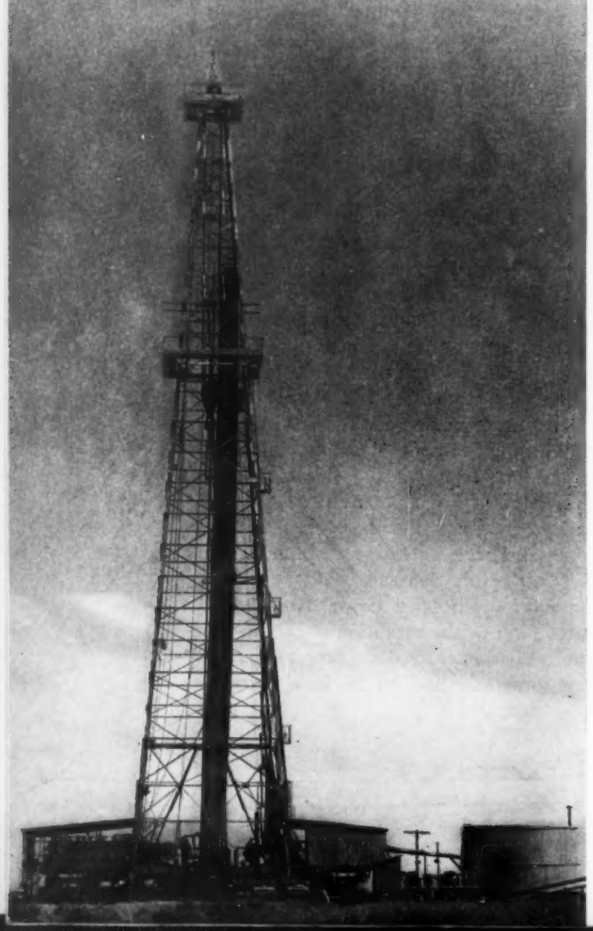
overproduction, or at least, potential overproduction, and proration developed as the instrumentality by which the physical basis for adequate conservation practices could be arrived at.

PRORATION

Proration has now evolved to the point where it clearly rests upon two thoroughly established principles—conservation and equity; and involves three procedures—curtailment of flow, ratable takings, and an adjustment of restricted flow to balance the measured requirements of the market. The system is administered by means of a quota system by which it is sought to bring into accord the requirements of waste prevention and market demand, without violation of the dictates of equity. In theory no pool is permitted to produce more than its market demand, it being recognized that output in excess of market demand leads to storage, physical waste, and economic instability; whereas restriction to market demand or to the most efficient rate, whichever is lower, results in effective conservation and economic advantage. It is difficult to differentiate accurately between the stabilizing effects derived from curtailment to efficient rates and those superimposed by the functioning of market-demand quotas, because any degree of restriction upon output necessitates operations under some measure of back pressure. The casual view that proration in essence is purely a stabilization measure is in error, for a substantial degree of the stabilization observable in practice is the automatic resultant of restricted flow and ratable takings instituted on the basis of conservation. It is impossible, for example, to operate an oil pool under back pressure without leveling-out the production curve and thereby flattening the cost curve; in consequence, a smoothing effect is transmitted to price. Under the practice of proration, therefore, entirely aside from the application of market-demand quotas, a significant byproduct of economic stability is inevitable.

In the operation of any economic system, of course, supply and demand must balance. Accordingly, if oil pools are to be restricted in the interest of conservation, the aggregate curtailment must conform to the dictates of demand, if consuming power is not to be regulated. Accordingly, the employment of market-demand quotas is a practical expedient to make the system workable, for existing demand does not coincide in all its ramifications with the various elements of supply at their respective optimum rates and hence an additional element of equilibration is necessary. Nevertheless the need for this additional element is probably not as great as generally believed, for judging from preliminary studies, the difference between the aggregate optimum production rate of American oilfields and market demand is not substantial; consequently proration can be directed so as to approach a plane of natural equilibrium between demand and a supply restricted according to engineering principles. At this stage, dependence upon market-demand quotas will be greatly lessened, if not entirely removed. This conclusion deserves the greatest emphasis, for the tendency in the industry is to overlook the advanced degree of evolution and hence to miss the point of greatest significance in the economics of the petroleum industry.

Photo by Knowles from Steel Oil Derrick Co.



Superior Oil Company has drilled more wells with tall derricks than any other concern. They use 175 ft. structures, with 32 ft. base and capacity of 952,000 lb., handling 120 ft. stands. Such rigs will make 10,000 ft. of hole in 24 days, a saving of 20 to 26 days per well compared with a 136 ft. derrick. Twelve days less drilling time and the derrick pays for itself. Left—Helbling No. 1, at Rio Bravo.

TWO AVENUES

Although proration appears to have its logical goal almost within its grasp, it is not assured that this instrumentality will be permitted to follow its natural courses to such an outcome. If the potentialities of proration were clearly envisaged by all concerned, this danger would not exist; but there are many who look upon proration solely as a stabilization device that is faulty because it fails to deliver all that is hoped of it on this score and hence desire to implement it with additional controls designed to achieve these ends. Such a course of development, in pursuit of transient and illusive gains, will lead to a condition of progressive economic regimentation that will destroy the vigor and flexibility of the industry, to the detriment of its profitability as an industrial enterprise and its serviceability to the public. On the other hand, the steps needed for the successful passage of proration into a perfected conservation measure, carrying with it a high degree of derived economic stabilization at the expense of minimum interference with competitive processes, are not complicated nor beyond reasonably early attainment.

SUGGESTED STEPS

The technique of proration is adequate for the purpose, all the necessary principles have become established, and a successful outcome waits merely upon a broader cooperation among the oil-producing states and concerted efforts on the part of the regulatory bodies, the Interstate Oil Compact Commission, and the oil operators. Five points are herewith offered for consideration:

1. Development of the optimum rate concept as a yardstick for restricting the individual oil pool.
2. Standardization of the application of bottom-hole pressure readings for the effectuation of ratable takings.
3. Harmonizing of drilling incentives with the requirements of delayed production.
4. Employment of market-demand quotas to reconcile the interim differences between optimum rates and market requirements.
5. Preservation of flexible markets to proportionate capital flow to economic requirements and prevent the development of intra-industry pressures.

OPTIMUM-RATE

In its more advanced areas of application, proration has established the optimum-rate concept as a working principle, although the significance of this accomplishment has not been fully appreciated. Experience has clearly demonstrated that the best results are obtained if the output of each pool is adjusted to its most efficient rate, and engineering technique is rapidly developing whereby this criterion can be broadly and effectively utilized. All that is needed to carry this measure to a position

of perfected application is the clear perception that this principle is the essence of conservation and constitutes the soundest base against which to equate demand. The regulatory bodies of the several states could advantageously study this matter intensively and formulate their policies more methodically in terms of it; for the system of proration is already logically committed to the principle and its application is well under way. It may be suggested, specifically, that the Interstate Oil Compact Commission appoint an Advisory Committee of Engineers to conduct a comprehensive field investigation of rates of production in terms of recovery efficiencies with the view of designing procedures and recommending standards of practice for the signatory states.

RATABLE TAKINGS

The principle of ratable takings is well established in proration practices, but its application is not fully standardized or adequately implemented. The principle is essential to the operation of proration and should be inviolate. The art of bottomhole pressure readings provides the technique for achieving a high degree of accurate control in the enforcement of the principle. Investigation and emphasis on the part of the regulatory bodies and the Interstate Oil Compact Commission would go far toward standardizing procedures and insuring systemetic and effective application. The purchasers of crude, likewise, should invariably conform to this principle whenever resort must be had to pipeline proration, a practice only necessary, however, when market-demand quotas are faultily determined. In its administrative aspects, ratable takings involves the establishment of lease allocation keyed to pool quotas designed to achieve the best attainable balance between optimum rates and market demand.

DRILLING RATES

Proration has brought about a system of delayed production divorced from the exigencies of the rule of capture, but drilling practices, while slowly adjusting themselves to the basic change in production rates, are still lagging in their conformance. It is believed that the disadvantages arising on this score are not fully appreciated, although the resulting disequilibrium may be diagnosed as the cause of much of the economic distress from which various groups in the industry are suffering. The fact is that drilling programs suitable to open-flow operations are obsolete under delayed production; but their unfitness, representing a natural lag in a changing setting, is subject only to slow correction until accelerated by adequately enlightened attitudes.

The administrators of proration still tend to make the well the ultimate unit of proration, thus placing a premium on the drilling of unnecessary wells; whereas the proper unit is the available oil in the individual property. A change to this basis, effectuated by formulæ for lease allocations involving acreage and by scientifically determined schedules for well spacing, would go far toward the correction of the existing trend toward overcapitalization of producing facilities. Effective proration requires the ability to expand the reserve without encouraging its premature development by wells in excess of market requirements. A shift in drilling incentives offers the means for harmonizing investments with delayed returns. High-cost producers dissatisfied with existing prices for crude oil would be well advised to take the lead in emphasizing the desirability of preventing the rule of capture from leading to an overinvestment in the producing department, for they are the first to suffer under such circumstances.

DEMAND QUOTAS

Market-demand quotas represent the most intricate phase of proration, for they involve problems of conflicting group and areal interests and introduce dangers of regimentation. The system of proration, accordingly, would do well to work toward a lessening of their incidence rather than in the direction of a growing dependence upon them. The restriction of production to market demand should properly be regarded as an interim expedient to reconcile existing differences between the most efficient production rates of oil pools and the essential requirements of the market. These differences are believed to be smaller than generally appreciated; hence progress can be rapid toward the effectuation of a system of proration based predominantly upon optimum production rates instead of market demand. Market-demand quotas, however, will continue to be helpful as an operating procedure, but their utility will diminish as engineering quotas founded upon optimum rate principles become more pervasively established and trade channels adjust themselves more completely to these measurements.

In the meantime, the market-demand quota system requires careful administration to avoid inequities and preserve essential flexibility in the commodity flow. Quotas should be constructed by determining the demand in each pool, limited in each case to not more than the most efficient production rate; but nominations to purchase are not satisfactory evidences of demand, and careful measurements are necessary to reflect valid changes in market requirements. The regulatory bodies can exercise accounting supervision over the gathering systems of each pool and not only audit the runs but also obtain an interim check upon conformance to the principle of ratable takings. Once this is done and each pool is restricted to the level of buyers' real requirements, the problem of overproduction is reduced to the question as to whether the aggregate buyers' demand is a fair reflection of the needs of the ultimate consumer. The regulatory bodies, however, with local demand accurately measured for each pool, can compare their respective totals with the advisory quotas of the U. S. Bureau of Mines, adjusting if necessary their field quotas by a proportional rate in order to

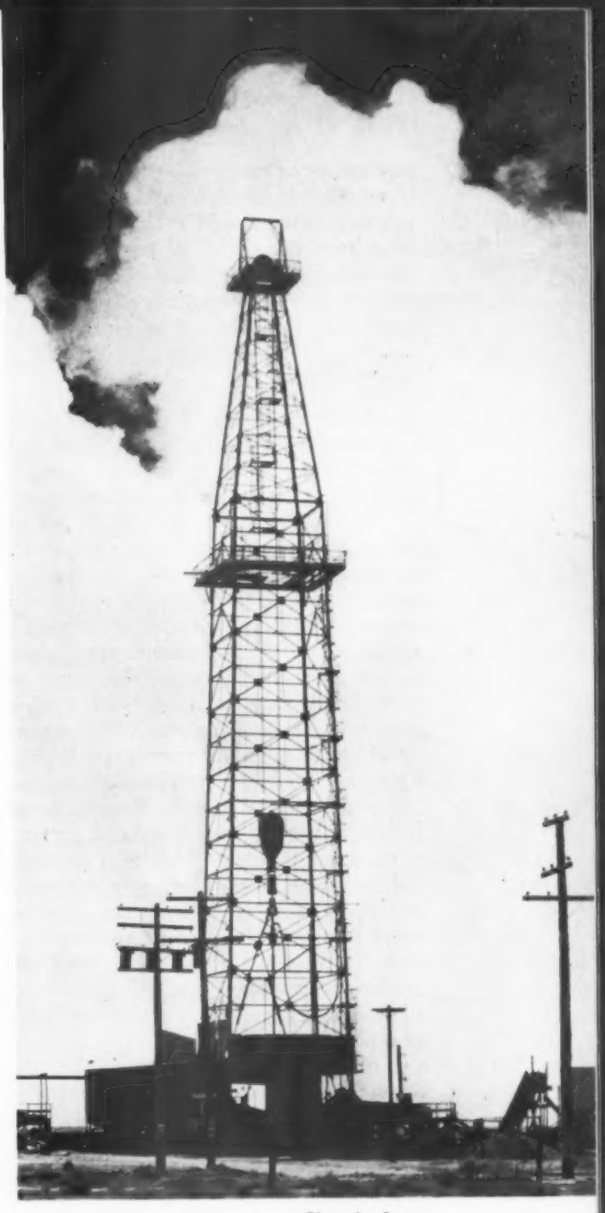


Photo by Inman

Something new in derrick design was erected by California Standard to drill its Mushrush No. 1 at Wasco. San Joaquin Valley operators call it the "Chysler Tower." It is 178 ft. high, 26 ft. at the base, 18 ft. at the run-around and 5½ ft. at the crown opening. Capacity is 960,000 lb. Design allows greater clearance in racking pipe as well as handling tall stands.

harmonize the totals with the requirements of equilibrium in the whole market. The advisory quotas should be based not merely upon past takings of oil but should also give reflection to the factors that determine the demands of the ultimate consumer in order that the quotas shall represent the best attainable approximations of balanced requirements.

FLEXIBLE MARKETS

Probably no single factor has harmed our economy more than the failure to appreciate and understand the functional aspect of prices. A price is both a cause and an effect, and it is impossible to maintain a given price without that price exerting an influence upon the flow of capital—attracting capital if the price is high, repelling capital if it is low. Because of the circumstances surrounding the establishment of proration and the nature of the incentives promoting its development, it has come to be widely believed that price is the criterion by which the success of proration may be judged; indeed there was a keen sense of disappointment and frustration on the part of oil operators when the price of crude oil declined in October, 1938, after five years of steady-to-rising prices. Yet nothing could be further from the truth than the view that proration fails if it does not produce a continued uptrend in price. If the price gets too high, excessive amounts of capital are drawn into development and the price declines; and contrariwise, the reverse reaction is induced if price falls too low. Proration, however, can legitimately be expected to provide a smoother and more stable price structure than would be attainable under open-flow operations; but the freedom of price to move up and down and therefore to influence the elements of supply, should be conserved at all hazards. As a matter of fact, the petroleum price structure has displayed considerable elasticity during the period of proration, but at times there has been a delayed transmission of flexibility resulting in the development of internal maladjustments; an improvement in functioning would undoubtedly result if tendencies toward localized rigidities were avoided. The promotion of a free and flexible market does not necessarily mean a low or nonremunerative price; on the contrary, there is much to suggest that a sensitive market may be expected to provide a more satisfactory price level in the presence of an effective administration of proration along the lines of optimum rate production than will be possible under any phase of controls designed for purely economic objectives.

CONCLUSION

Considering the physical, economic, and legal complications surrounding the field of oil production, it is a substantial achievement on the part of the petroleum industry to have so quickly and, relatively speaking, so successfully altered the structure of production to bring it into conformance with the technologic era. The new system is far from perfected, but the striking feature is the progress made and the vigor displayed in furthering the evolution. The suggestions advanced in this study are not novel, for the five points are well under way to accomplishment, needing merely a more concerted attitude to coordinate efforts, avoid dissipation of energy in by-paths, and prevent deflection of the natural direction of movement. Proration is not assured of a favorable outcome, for there is pressure to convert it into a pervasive economic control, but time and administrative skill can bring to sound fruition one of the most significant experiments in the economic field today.

ADDITIONS TO BAHREIN REFINERY

A CATALYTIC polymerization plant is being constructed in The Bahrein Petroleum Company Ltd.'s refinery at Bahrein Island. Butylene and propylene produced during the cracking and reforming operations will be polymerized into motor gasoline polymers, and the process developed by Standard of California will be used. The polymerization will take place in the vapor phase in contact with a phosphoric acid catalyst in chambers operating at about 200 lb. per sq. in.

The installation involves not only the polymerization unit itself but a rather complicated system for separating and pretreating the olefin feed cut and for after-stabilization of the polymers. Installation of the plant also requires supplementing steam generating facilities.

There are two cracking units having a combined charging rate of 12,000 bbl. per stream day when operating to coke and one 6,000 bbl. per stream day reformer in operation in the refinery. The polymerization plant is being constructed sufficiently large to handle the volume of olefin feed when all three units are operating at capacity. The olefin feed cut will be available as a liquid under pressure amounting to about 2,800 bbl. per stream day. The butane-free rerun polymer gasoline will amount to approximately 900 bbl. per operating day when running at capacity.

The motor gasoline polymers which will be available when the plant goes into operation will materially facilitate production of high octane motor gasoline from Bahrein and Arabian crudes. In addition to providing flexibility in blending and enabling the refinery to ship special high octane grades, operation of the polymer plant will add appreciably to the total volume of the gasoline produced in the refinery by reason of reduced reforming losses as well as by production of the polymer gasoline itself.

GULF EXPORT PRICES FOR MAJOR OIL PRODUCTS

Products		Jan. 18	Jan. 25	Feb. 1
		Cents Per Gallon		
GASOLINE:	U.S. Motor	4¾	4¾	4¾
	64/66-375 E.P.	4¾	4¾	4¾
	59 Octane and below	4¾	4¾	4¾
	65 Octane and above	4½	4½	4½
AVIATION GASOLINE:	Gulf Export in cargo lots	8¼	8¼	8¼
KEROSENE:	44 w.w.	4⅛	4⅛	4⅛
	41/43 w.w.	3⅞	3⅞	3⅞
	41/43 p.w.	3⅞	3⅞	3⅞
GAS OIL:	43 Diesel Index and below	3⅜	3⅜	3⅜
	43/47 Diesel Index	3½	3½	3½
	48/52 Diesel Index	3½	3½	3½
	53/57 Diesel Index	3⅝	3⅝	3⅝
		Dollars Per Barrel		
FUEL OIL:	Bunker C	75	75	75
	Cargo lots	67½	67½	67½
	Diesel oil	1.55	1.55	1.55
		Cents Per Gallon		
LUBRICATING OIL:	Bright Stock No. 8	21½	21	21½
	Bright Stock No. 6½	21½	21½	21½
	600 Warren E	20½	20½	20½
	600 Unfiltered s.r.	15½	15	15
(New York Export)	650 Unfiltered s.r.	16½	16	16
	600 Flash s.r.	17½	17½	17½
	630 Flash s.r.	20½	20½	20½
	Neutral 200 No. 3	22½	22½	22½
	Neutral 150 No. 3½	20½	20½	20½
(South Texas Export)	Red oil 500 No. 5-6	7½	7½	7½
	750	8	8	8
	1200	8⅜	8⅜	8⅜
	Pale oil 500	7½	7½	7½
	750	8	8	8
	1200	8⅜	8⅜	8⅜
		Dollars Per Barrel		
CRUDE OIL:	East Texas delivered at Gulf for export	1.25	1.22	1.22½

1,960,354,909 BBL. Produced in 1938

Production of United States and Rest of World Shows 3.9 Percent Decline from 1937 Total—Russia, Netherland India, Colombia, Trinidad, Argentina, and Bahrein Only Major Producers with Appreciable Gains—Canadian Output More Than Double Last Year's—Saudi Arabia Appears in 22nd Place Among 30 Producers.

DESPITE the fact that most of the world's major oil producers failed to show appreciable gains—some lost considerable ground—during 1938 there were several changes in relative positions among the countries half-way down the list.

United States still led the world with 61.8 percent of the total output in 1938, although it is a decline in relative importance from the 62.7 percent of 1937.

Soviet Russia increased its output by over 4,000,000 bbl. during the year, while Venezuela failed to consolidate its steady increase of former years and declined. Most of Netherland India's rise in production came from Sumatra. Roumania suffered a further set-back while the situation engendered in Mexico by the unwarranted expropriation of oil properties was reflected in the marked drop in crude recoveries.

The slight increase in Iraq oil statistics is probably to some extent due to increased consumption in Iraq and adjacent countries, inasmuch as shipments are limited to the capcity of the pipeline to tide-water. Colombian production rose appreciably, while the increase of output in Trinidad brought that country from 12th place in 1937 to 10th in 1938. Argentine crude oil production rose to a small extent, but Peruvian wells yielded almost 2,000,000 bbl. less than during the previous twelve months, reducing that country to 12th place.

Bahrein fulfilled its threat of 1937 by changing places with Burma for 13th in order of importance, while the production of the latter country as indicated by preliminary figures may be less than that of 1936.

Flow of petroleum from the Alberta wells was more than double that of 1938 and brought Canada from 18th position in 1937 to 15th in 1938. Although Brunei fell from 15th to 16th place relative to the other producers, nevertheless its production increase in 1937 was considerable. Both the fields of Old Reich and of Ostmark (former Austria) in Germany showed gains of appreciable domestic importance.

Intensified drilling and exploration activity in Poland, together with government encouragement of the international oil companies operating there has resulted in the checking of the rapid decline in well output of that country. The production curve showed a slight upturn in 1938—although Poland is now down to 18th place from its former status of 16th most important country in 1937. Japan, British India, and Ecuador showed small increases in 1938.

A new-comer, Eastern Saudi Arabia, would hold 26th place on the basis of its total 1938 yield, but inasmuch as the Damman field was only put into commercial operation at the end of September, it is the daily average for the last quarter which must be considered—putting it ahead of Sarawak in 22nd place. Sarawak production dropped off a little in 1938, while the addition of the Ras Ghareb field in Egypt brought its actual production up, although it dropped back to 24th place.

Albania not only failed to make the great strides planned for it during 1938, but showed an appreciable decline and dropped from 24th to 26th position. The only other change of significance among the smaller countries was Hungary's stepping up from 30th to 27th place. If production is developed according to expectations, as is quite possible, Hungary will be able to meet practically all her consumption by September, 1939, with daily output. 4,400 bbl.

The increase of "Other Countries" is due to the production obtained in Kuweit, which is not yet being opened up for commercial exploitation.

Relative importance of the principal petroleum producing areas of the world in proportion to the total, based on preliminary figures received by this journal—figures in thousands of barrels. Areas in red decreased in 1938; those in green showed an increase over 1937.

WORLD OIL

All figures furnished direct to WORLD PETROLEUM by governments, except where otherwise specified

U. S. BARRELS

	January 1938	February 1938	March 1938	April 1938	May 1938	June 1938	July 1938	August 1938	Sept. 1938	Oct. 1938	Nov. 1938	Preliminary Figures Dec. 1938
United States	106,007,000	94,662,000	106,524,000	102,702,000	98,674,000	94,277,000	102,898,000	106,165,000	98,661,000	101,830,000	98,567,000	**100,530,000**
Soviet Union[4]	17,647,000	13,591,000	15,984,000	17,850,000	17,580,000	18,540,000	18,200,000	17,600,000	17,500,000	17,400,000	17,250,000	**17,050,000**
Venezuela	15,271,902	13,792,479	15,109,040	13,696,219	15,994,400	16,302,150	14,912,555	16,616,673	16,271,096	17,352,171	16,356,204	**16,744,163**
Iran[5]	5,907,458	6,414,470	8,284,215	7,090,486	6,975,256	5,792,228	5,338,990	5,861,366	5,676,998	7,136,578	7,221,080	**6,400,000**
Netherland India: Sumatra	2,674,572	2,587,988	2,912,764	2,809,415	2,971,443	2,893,856	2,814,237	2,901,321	2,917,167	3,049,196	3,015,432	**3,177,589**
Borneo	1,123,800	1,008,290	1,114,431	1,056,224	1,066,281	1,013,163	1,061,980	970,690	1,069,872	1,123,102	1,090,009	**1,114,535**
Java[9]	637,102	590,763	643,568	639,582	674,927	616,845	585,086	524,384	482,417	523,623	515,160	**529,658**
Ceram	53,215	48,388	50,377	52,329	51,524	49,870	54,035	54,825	50,355	50,444	45,750	**[1]45,773**
Roumania	4,099,000	3,751,692	4,182,000	4,090,000	4,169,000	4,015,000	4,115,000	4,075,736	3,915,029	4,028,750	3,847,324	**3,969,300**
Mexico	4,141,977	4,016,000*	1,226,368*	1,912,493*	2,301,995*	2,374,815*	2,000,000[1]	3,895,453*	3,250,000[1]	3,500,000[1]	3,275,000[1]	**2,900,000**
Iraq	2,670,844	2,385,464	2,717,278	2,592,996	2,332,746	2,653,579	2,806,903	2,829,528	2,621,547	2,431,949	2,420,143	**2,290,777**
Colombia	1,784,638	1,508,487	1,841,882	1,642,195	1,819,689	1,826,136	1,826,848	1,870,013	1,797,158	1,891,825	1,863,838	**1,880,000**
Trinidad	1,378,021	1,304,819	1,438,436	1,418,825	1,481,285	1,431,476	1,500,171	1,505,959	1,514,893	1,594,480	1,503,489	**1,664,322**
Argentina[1]	1,378,000	1,289,000	1,380,000	1,349,000	1,382,000	1,346,000	1,349,000	1,360,000	1,358,000	1,360,000	1,358,000	**2,028,000**
Peru[3]	1,365,152	1,224,437	1,474,364	1,296,090	1,343,259	1,303,536	1,335,623	1,328,143	1,280,691	1,331,111	1,303,990	**1,321,883**
Bahrein[6]	805,800	707,379	737,164	692,403	620,746	661,602	699,176	713,149	714,349	708 962	613.281	**263,987**
Burma[7]	616,522	496 306	633,644	635,903	667,346	679,368	638,000[1]	635,000[1]	650,000[1]	635,000[1]	650,000[1]	**635,000**
Canada[2]	457,408	413,158	480,803	464,316	566,086	537,654	693,332	817,706	886,111	685,088	445,514	**489,303**
Brunei[8]	409,592	381,052	445,194	428,889	445,505	425,184	453,393	448,219	478,080	477.459	484,207	**510,500**
Great Germany: Old Reich[14]	268,028	257,967	355,684	342,387	329,688	326,842	346,435	342,484	328,098	331,792	307,433	**328,000**
Ostmark[15]	25,620	28,160	30,070	29,100	32,845	30,000[1]	31,062	29,453	26,772	43,697	29,000[1]	**30,000**
Poland	318,928	293,232	327,077	315,768	324,803	315,381	314,000[1]	328,115	321,134	326,000[1]	318,000[1]	**326,000**
Japan[10]	218,594	214,191	214,820	207,522	216,078	216,707	216,707	217,525	170,597	220,451	224,255	**220,000**
British India[11]	196,697	132,164	197,792	196,543	198,872	192,656	195,000[1]	200,000[1]	197,800[1]	195,000[1]	198,000[1]	**195,000**
Ecuador	187,525	171,138	191,746	181,331	190,542	188,712	192,360	193,534	189,037	192,702	185,669	**192,882**
Saudi Arabia	2,523	4,155	2,622	2,382	3,794	3,477	3,550	3,459	40,556	136,947	152,632	**139,038**
Sarawak[12]	137,497	126,578	137,281	133,248	137,824	132,940	132,007	107,102	123,476	223,165	115,952	**118,512**
Egypt[13]	91,927	84,974	94,545	88,555	89,935	84,998	83,412	143,978	157,533	208,377	211,841	**221,156**
France	41,560	40,840	43,589	42,839	48,545	43,189	43,574	43,000[1]	41,104	43,000[1]	42,000[1]	**48,000**
Albania[16]	42,400	39,200	42,400	41,000	42,400	72,300	46,049	4,998	68,655	Nil	42,000[1]	**43,000**
Hungary	13,744	12,461	13,976	13,775	18,691	26,018	25,888	30,900[1]	38,240	49,800[1]	52,000[1]	**66,000**
Czechoslovakia	11,070	10,437	12,158	10,731	10,960	10,159	9,333	11,015	10,933	13,747	10,502	**11,000**
Bolivia	10,302	7,128	9,100[1]	8,800[1]	9,000[1]	8,790[1]	9,500[1]	9,200[1]	8,500[1]	8,800[1]	8,500[1]	**9,000**
Italy	9,048	7,969	9,612	9,459	9,563	8,646	9,378	9,057	8,267	8,622	7,000[1]	**8,000**
Other Countries[17]	6,000	5,400	6,000	5,800	6,000	5,800	6,000	6,000	50,000	48,000	50,000	**48,000**
WORLD TOTAL	170,010,466	151,609,166	168,898,000	164,048,545	162,787,023	158,405,367	168,952,818	172,852,085	162,875,465	169,129,838	161,780,205	**165,548,378**

[1] Estimate.
[2] Includes natural gasoline production.
[3] International Petroleum Company and Lobitos Oilfields Ltd. figures combined.
[4] Russian Sakhalin included with U.S.S.R.
[5] Anglo-Iranian Oil Company Ltd. figures revised—fuel oil returned to the ground has been deducted.
[6] Bahrein Petroleum Company Ltd. figures.
[7] Does not include Assam or Punjab, which are listed together under British India.
[8] British Malayan Petroleum Company Ltd. figures.
[9] Includes Madura.

Official Crude Oil Production Figures for 1932 to 1938 (Revised) in Barrels

	Daily Av. 1938	Daily Av. 1937	Preliminary Total 1938	Total 1937	Total 1936	Total 1935	Total 1934	Total 1933	Total 1932
United States	**3,319,170**	3,504,200	**1,211,497,000**	1,279,160,000	1,098,516,000	996,596,000	908,065,000	905,656,000	785,159,000
Soviet Union	**564,909**	553,031	**206,192,000**	201,856,661‡	199,635,921	184,008,033	175,635,783	155,596,429	155,927,997
Venezuela	**475,360**	514,179	**173,506,497**	187,675,477	155,270,840	148,809,057	136,098,681	117,113,940	115,615,782
Iran	**213,970**	213,997	**78,099,125**	78,109,001	62,977,950	57,520,488	57,902,092	54,440,075	49,516,697
Netherland India: Sumatra	**95,167**	91,648	**34,735,997**	33,451,511	30,469,428	28,004,595	26,336,011	22,345,172	18,570,928
Borneo	**35,102**	35,507	**12,812,383**	12,960,072	13,068,910	13,529,185	14,335,543	15,003,175	15,228,615
Java	**19,074**	19,597	**6,962,122**	7,152,931	3,618,293	3,462,440	3,778,920	3,600,816	3,837,142
Ceram	**1,663**	1,472	**608,963**	537,436	375,823	311,872	273,698	285,335	309,957
Roumania	**132,508**	143,549	**48,366,000**	52,395,725	63,532,846	61,270,072	61,849,306	53,919,708	53,651,978
Mexico	**95,325**	127,102	**34,793,701**	46,455,687‡	41,027,915	40,240,563	38,171,946	34,000,830	32,805,496
Iraq	**84,257**	83,846	**30,753,754**	30,603,660‡	29,913,150	27,410,983	7,639,849	1,094,915	871,840
Colombia	**61,506**	55,609	**22,449,709**	20,297,543‡	18,756,110	17,597,655	17,337,900	13,156,126	16,415,214
Trinidad	**48,592**	42,474	**17,736,176**	15,502,989	13,237,030	11,671,224	10,894,363	9,561,353	10,126,121
Argentina	**46,403**	44,807	**16,937,000**	16,354,717	15,457,960	14,297,025	14,021,901	13,690,556	13,138,747
Peru	**43,584**	47,833	**15,908,279**	17,459,112	17,593,069	17,056,555	16,314,381	13,257,318	9,899,265
Bahrein	**22,734**	21,266	**8,297,998**	7,762,264	4,644,635	1,264,807	285,072	31,377	902
Burma	**20,748**	21,500	**7,572,089**	7,847,553	7,587,718	7,181,113	7,278,859	7,114,311	7,073,437
Canada	**19,004**	8,206	**6,936,479**	2,995,025	1,507,931	1,447,204	1,410,895	1,145,333	1,044,412
Brunei	**14,759**	12,047	**5,387,214**	4,397,038	3,296,938	3,302,905	2,705,350	2,035,656	1,200,026
Great Germany: Old Reich	**10,589**	8,626	**3,864,838**	3,148,300	3,076,858	2,967,438	2,204,402	1,656,602	1,594,807
Ostmark	**1,002**	606	**365,779**	221,266	50,092	44,347	27,965	5,765	804
Poland	**10,489**	10,411	**3,828,438**	3,799,862	3,869,575	3,901,881	4,011,336	4,174,079	4,219,634
Japan	**7,006**	6,816	**2,557,447**	2,487,841	2,403,072	2,294,878	1,872,837	1,504,412	1,683,439
British India	**6,281**	5,923	**2,292,524**	2,161,653	1,978,329	2,037,810	1,921,863	1,628,803	1,743,878
Ecuador	**6,184**	5,922	**2,257,278**	2,161,436	1,942,467	1,731,785	1,636,619	1,619,902	1,597,641
Saudi Arabia	**1,356**	178	**495,135**	64,968	19,777	Nil	Nil	Nil	Nil
Sarawak	**4,452**	4,535	**1,624,882**	1,655,565	1,547,882	1,776,593	1,942,591	2,206,815	2,329,733
Egypt	**4,277**	3,187	**1,561,231**	1,163,267	1,262,666	1,255,151	1,527,252	1,653,535	1,071,976
France	**1,414**	1,389	**516,240**	507,067	534,063	529,664	700,000	786,366	755,146
Albania	**1,341**	1,621	**489,402**	591,677‡	219,693	41,218	17,500	11,437	9,212
Hungary	**990**	38	**361,493**	13,910	100	Nil	Nil	Nil	Nil
Czechoslovakia	**362**	336	**132,045**	122,790	126,603	136,580	177,797	121,695	126,603
Bolivia	**292**	337	**106,620**	123,123	104,746	163,295	157,875	111,973	41,907
Italy	**288**	317	**105,071**	115,801‡	129,653	128,615	162,449	213,534	242,563
Other Countries	**665**	192	**243,000**	70,000	37,100	32,300	64,000	54,100	73,300
WORLD TOTAL	**5,370,822**	5,592,504	**1,960,353,909**	2,039,875,130	1,797,891,143	1,652,023,331	1,516,760,036	1,438,797,443	1,305,574,242

‡Preliminary.

PRODUCTION

Figures in U. S. barrels of 42 gal.—Conversion ratios used are weighted averages for individual countries

METRIC TONS

	Jan. 1938	Feb. 1938	March 1938	Apr. 1938	May 1938	June 1938	July 1938	Aug. 1938	Sept. 1938	Oct. 1938	Nov. 1938	Preliminary Figures Dec. 1938
United States	14,345,022	12,814,670	14,420,469	12,916,610	13,357,804	12,762,583	13,939,606	14,507,243	13,189,481	13,785,028	13,343,306	13,609,000
Soivet Union[4]	2,421,000	2,440,000	2,192,000	2,448,000	2,411,000	2,543,000	2,497,000	2,414,000	2,401,000	2,387,000	2,366,000	2,339,000
Venezuela	2,256,820	2,038,197	2,232,753	2,023,972	2,363,588	2,409,066	2,205,195	2,455,545	2,404,477	2,564,234	2,417,054	2,474,385
Iran[5]	781,304	848,360	1,095,647	937,768	922,528	766,064	706,120	775,208	750,824	943,864	1,039,640	845,000
Netherland India: Sumatra	359,003	347,381	390,975	378,445	398,988	388,437	377,750	389,439	391,566	409,288	404,756	426,522
Borneo	150,847	135,341	149,588	141,775	143,124	135,995	142,549	130,294	143,607	150,752	146,310	149,602
Java[9]	85,517	79,297	86,385	85,850	90,460	82,798	78,535	70,387	64,754	70,285	515,160	71,095
Ceram	7,143	6,495	6,762	7,024	6,916	6,694	7,253	7,359	6,759	6,771	45,750	6,144
Roumania	559,973	512,175	570,239	558,362	568,874	548,139	561,775	556,415	534,475	550,000	525,232	541,884
Mexico	614,902	596,200*	182,061*	283,921*	341,745*	352,555*	297,000[1]	444,693	482,500[1]	519,600[1]	486,200[1]	430,000
Iraq	358,118	319,853	364,344	347,948	312,771	355,803	376,415	379,395	351,508	326,086	324,503	312,734
Colombia	248,730	210,242	256,700	228,878	253,615	254,514	254,669	260,629	250,475	263,669	259,768	262,100
Trinidad	193,923	183,622	202,425	199,666	208,456	201,446	211,113	211,928	213,185	224,385	211,580	234,214
Argentina[1]	196,300	183,600	198,000	192,200	196,900	191,900	192,200	193,800	193,500	194,000	193,500	288,930
Peru[3]	180,911	162,263	195,383	171,759	178,010	172,745	168,725	176,006	167,718	177,893	172,805	175,667
Bahrein[6]	109,751	95,450	100,478	94,457	84,723	90,435	95,428	97,279	97,479	96,660	83,585	85,009
Burma[7]	85,120	69,240	91,765	87,796	92,275	93,797	87,900[1]	87,800[1]	89,100[1]	87,800[1]	89,100[1]	87,800
Canada[2]	57,783	52,193	60,739	58,649	71,511	67,934	87,586	103,298	111,686	86,545	56,280	61,812
Brunei[8]	54,623	49,965	58,376	56,230	58,416	55,552	59,464	58,772	62,688	62,607	63,491	66,939
Great Germany: Old Reich[14]	38,604	37,155	51,517	49,314	47,485	47,075	49,897	45,007	47,256	47,788	45,865	47,200
Ostmark[15]	5,816	5,253	5,820	5,627	4,900	5,800[1]	4,634	4,394	3,994	6,519	5,600[1]	5,800
Poland	42,075	38,685	43,150	41,658	42,850	41,607	41,000[1]	43,287	42,366	43,000[1]	42,000[1]	43,000
Japan[10]	30,070	30,481	30,586	29,518	30,750	30,839	30,839	30,955	24,277	31,376	31,913	31,000
British India[11]	27,157	18,247	27,308	27,136	27,357	26,599	27,000[1]	27,600[1]	27,300[1]	27,000[1]	27,300[1]	27,000
Ecuador	26,577	24,254	27,175	25,699	27,004	26,743	27,262	27,412	26,791	27,310	26,314	27,336
Saudi Arabia	323	516	328	305	492	451	460	453	5,498	18,570	20,697	18,590
Sarawak[12]	18,337	16,597	18,001	17,472	18,072	17,340	17,309	13,913	16,191	16,150	15,204	15,540
Egypt[13]	13,365	12,005	13,516	12,660	12,642	12,151	11,924	20,583	22,521	29,789	30,285	31,617
France	5,820	5,579	6,104	5,999	6,798	6,048	6,102	6,000[1]	5,756	6,000[1]	5,900[1]	6,000
Albania[16]	6,200	5,650	6,200	6,060	6,200	10,790	6,873	746	10,247	Nil	6,200[1]	7,000
Hungary	1,778	1,612	1,808	1,782	2,418	3,366	3,349	4,000[1]	4,947	6,400[1]	6,700[1]	8,600
Czechoslovakia	1,617	1,526	1,776	1,566	1,601	1,484	1,521	1,609	1,597	2,008	1,534	1,600
Bolivia	1,295	897	1,140[1]	1,110[1]	1,130[1]	1,100[1]	1,200[1]	1,160[1]	1,000[1]	1,100[1]	1,000[1]	1,130
Italy	1,124	990	1,194	1,175	1,188	1,074	1,164	1,125	1,027	1,071	1,000[1]	1,050
Other Countries[17]	850	770	850	830	850	830	850	850	7,000	6,700	7,000	6,700
WORLD TOTAL	23,287,788	21,344,763	23,091,564	21,441,537	22,293,441	21,512,754	22,567,667	23,548,584	22,154,494	22,177,248	23,018,532	22,747,000

[10] Japanese Sakhalin, Taiwan (Formosa) and Hokkaido included with Japan.
[11] Excluding Burma.
[12] Sarawak Oilfields Ltd. figures.
[13] Anglo-Egyptian Oilfields Ltd. figures.
[14] Prussia, Thuringia and Baden.
[15] Formerly known as Austria.
[16] Italian imports of Albanian crude oil.
[17] Nominal figure representing proportion to world total represented by: Morocco, Cuba, New Zealand, Barbados, Greece, Algeria, Yugoslavia, Australia, Great Britain, Kuwait and China.
* Official Figures—Petroleos Mexicanos.

Official Crude Oil Production Figures for 1932 to 1938 (Revised) in Metric Tons

	Daily Av. 1938	Daily Av. 1937	Preliminary Total 1938	Total 1937	Total 1936	Total 1935	Total 1934	Total 1933	Total 1932
United States	446,550	473,487	162,990,822	172,822,797	148,707,864	134,912,143	122,913,903	122,601,191	106,289,292
Soviet Union	79,066	76,348	28,859,000	27,867,025‡	27,384,900	25,241,100	24,092,700	21,330,100	21,389,300
Venezuela	76,288	75,983	27,845,286	27,733,926	22,945,299	21,990,373	20,112,115	17,293,193	17,085,334
Iran	28,527	28,303	10,412,327	10,330,480	8,329,289	7,607,500	7,657,970	7,200,093	6,548,941
Netherland India: Sumatra	12,774	12,302	4,662,550	4,490,137	4,114,710	3,759,006	3,535,035	2,999,352	2,492,742
Borneo	4,712	4,766	1,719,783	1,739,607	1,773,545	1,815,998	1,924,234	2,013,849	2,043,707
Java	2,560	2,630	934,513	960,125	499,097	464,757	510,320	483,331	515,187
Ceram	224	198	81,740	72,139	50,446	41,862	36,738	38,300	41,605
Roumania	18,090	19,597	6,603,000	7,153,000	8,704,000	8,394,000	8,473,355	7,387,000	7,350,321
Mexico	13,785	18,887	5,031,377	6,896,657‡	6,090,842	5,973,955	5,666,857	5,049,109	4,870,175
Iraq	11,314	11,305	4,129,478	4,126,185‡	4,079,066	3,724,231	1,048,108	147,943	118,887
Colombia	8,230	7,792	3,003,809	2,844,251‡	2,614,092	2,452,635	2,416,432	1,833,606	2,287,835
Trinidad	6,748	5,977	2,462,943	2,181,676	1,862,796	1,642,446	1,533,122	1,345,532	1,425,009
Argentina	6,610	6,384	2,413,000	2,330,063	2,202,304	2,036,903	1,997,706	1,950,499	1,871,882
Peru	5,733	6,339	2,099,885	2,313,691	2,331,454	2,260,903	2,161,990	1,756,867	1,311,856
Bahrein	3,098	2,900	1,130,734	1,058,557	635,555	173,072	39,008	4,293	123
Burma	2,875	2,968	1,049,493	1,083,391	1,047,593	991,456	1,004,951	982,233	976,589
Canada	2,400	1,037	876,016	378,430	190,495	182,820	178,233	144,686	131,937
Brunei	1,937	1,580	707,123	576,545	470,991	471,842	386,478	290,808	171,432
Great Germany: Old Reich	1,518	1,242	554,163	453,451	444,600	427,400	317,500	238,600	229,700
Ostmark	176	91	64,157	33,010	7,473	6,616	4,172	860	120
Poland	1,383	1,373	504,678	501,301	510,630	514,760	529,200	550,670	556,680
Japan	993	970	362,604	354,040	341,976	326,580	266,520	212,667	239,567
British India	868	818	317,004	298,450	273,137	281,072	265,341	224,879	240,767
Ecuador	876	839	319,877	306,326	275,293	245,434	231,947	229,578	226,423
Saudi Arabia	183	22	66,683	8,070	2,447	Nil	Nil	Nil	Nil
Sarawak	548	595	200,126	217,085	221,126	253,799	277,513	315,259	332,819
Egypt	611	456	223,058	166,298	177,491	176,436	214,671	232,437	265,055
France	198	194	72,106	71,008	74,788	74,172	98,025	110,120	105,758
Albania	198	242	72,166	88,310	32,760	6,152	2,500	1,707	1,375
Hungary	128	38	46,760	13,910	13	Nil	Nil	Nil	Nil
Czechoslovakia	53	49	19,439	17,936	18,665	19,946	25,971	17,776	18,493
Bolivia	36	42	13,262	15,487	13,197	20,540	19,858	14,085	5,284
Italy	36	39	13,182	14,261	16,106	15,977	20,180	26,526	27,046
Other Countries	93	27	34,080	10,000	5,300	4,600	9,100	7,700	10,500
WORLD TOTAL	739,439	765,820	269,896,224	279,541,200	240,539,340	226,410,486	207,970,753	197,024,849	179,181,741

‡Preliminary Total

FEDERAL-STATE Controversy on Ownership of Coastline Oilfields Likely

By Samuel W. Bell

THE question of title to the petroleum deposits in submerged pools along the seaboard of certain states again has been placed before Congress, this time reinforced in behalf of the Federal Government, officials believe, by the current agitation for national defense.

The question has been projected by Senator Nye of North Dakota in the form of the same resolution which passed the Senate last year only to die on the House calendar after it had been reported by the Judiciary Committee in emasculated form. The resolution authorizes the Attorney General to assert claim and take court action to vest title to all such undersea lands in the government for their conversion into Naval oil reserves.

Amounting as it does to a challenge to California's title to deposits estimated to be worth $2,000,000,000 and valuable underwater areas along the coasts of Texas and Louisiana delegations from those states are organizing to make a fight in the Senate Public Lands Committee. Assistance from other states, contending that the government can lay title to nothing within the three-mile limit, excepting navigable waters is also expected.

Senator Connally of Texas, asking for a hearing, has told the committee that the Nye proposal is threat to all states bordering on the ocean. State officials of Florida have asked a chance to present arguments against such legislation and the Californians have appointed a strategy group consisting of Senator Johnson and Represenatives Lea, Carter and Tolan.

Although contending that the question is purely a matter of law and not susceptible to adjudication by general testimony, Senator Adams of Colorado, chairman of the Public Lands Committee, had said he will not oppose a thorough discussion providing prospective witnesses can make any contributions.

Thus far the Navy Department's declared wishes are for conservation only of such pools off California. The Navy, in the San Joaquin Valley, maintains Naval Petroleum Reserves No. 1 and 2. According to recent estimates by Commander William G. Greenman, inspector of naval petroleum reserves, these now constitute less than 20,000 acres of what at this time may be called good oil land.

Even this land, the Navy contends, is threatened by drainage from private property checkerboarded within it and steady depletion by developments along the eastern border. Recent legislation has authorized the Secretary of the Navy to consolidate the reserve by removing private land through exchanges or purchase, but there is grave question in the minds of naval officers as to whether this reserve, as it stands, contains oil which can be recovered with sufficient rapidity and in ample quantities should other sources fail.

As the result of these conditions the Navy Department recently directed a survey of the California industry to determine the extent of the reliance that could be placed on the future crude supply of the state in relation to national defense. According to Commander Greenman reserves in the United States are estimated at more than 15,000,000,000 bbl. and at the present time about 20 percent of this volume or 3,000,000,000 bbl., is estimated to be in California. He emphasized, however, that this apparent great volume of California reserve oil represents but 80 percent of the estimated state reserves of 10 years ago; and that at the rate of discovery of new reserves over that period, this apparently inexhaustible source of supply is being depleted at the rate of 100,000,000 bbl. a year.

In the last year Commander Greenman pointed out 250,000,000 bbl. were withdrawn from the reservoirs of the state and of this amount 33,000,000 bbl. could not be absorbed by the abnormally expanded markets of the state. In other words domestic demand on the West Coast falls short of production and more than 30 percent is shipped out, the greater portion of the latter going to the warring nations of Europe and the Far East, much of which is sold at no profit in order to relieve the surplus. During 1938, he added, 30,000,000 bbl. of crude and refined products were shipped to Japan alone, an increase of 2,000,000 bbl. over the year before.

The Navy Department study showed, he said, that there is no machinery or organization in the state government of California responsible for obtaining and disseminating information as to the state's petroleum resources and no real effort has been made to enact legislation for this purpose.

Considering these things Commander Greenman stated that it is the firm belief of the Navy Department that the people have a right to know what steps are being taken to conserve the remaining untouched petroleum products in this strategically located state. Much of the reserve underlies the submerged lands.

In attempting to establish ownership, he explained, the Navy Department has no thought or desire to take anything from anyone having prior rights or make an arbitrary grab. However, the Department does believe it is the duty of California and the federal government to demand that ample reserves of oil be maintained in the ground in the Pacific Coast fields in the interest of national defense.

Except for the promised controversy over the Nye resolution the first month of the Seventy-Sixth Congress has been devoid of developments affecting the petroleum industry. No move has been made thus far to initiate legislation covering the Connally (hot oil) act which expires June 30. Bills introduced deal with familiar proposals to levy an excise tax on oil imports and divorce the business of production, refining and transporting petroleum products from the marketing operation.

Senator Gillette of Iowa has introduced a full-fledged bill for the separation of producing and refining branches of the industry from marketing while Representative Daly proposes to amend the Interstate Commerce Act to make it unlawful for railroads to maintain pipelines except for water, natural and artificial gas.

As the last of the 37 members of the crew of the tanker "Jaguar" clambered aboard the rescuing freighter "Duala" in mid-Atlantic, January 19th. The day before the "Jaguar" had broken in two and the sections drifted 10 miles apart before sinking.

International News Photo

SIR HENRI DETERDING

SIR HENRI DETERDING, former head of the Royal Dutch-Shell Group and one of the international oil industry's outstanding leaders, died of a heart attack at his villa in St. Moritz, Switzerland, February 4th. He was 72 years old.

As Rockefeller had grown up with the kerosene age, so Sir Henri's career paralleled the development of gasoline. Born in Amsterdam, the fourth of five children sired by a simple seaman, he lost his father when only six and had to work as a bank clerk in his early teens at $1.25 per week.

Sent out to the colonies as an expert accountant he grasped the opportunity, when he was 20, to join a pioneer oil man, J. B. Aug. Kessler, in a small company known as the Royal Dutch Petroleum Company. Merging with other small concerns he acquired enough corporate strength to establish his company as a worthy competitor of Standard Oil in the Far East.

Sir Henri's activities in international trade were facilitated by a mastery of English, French and German as well as his native Dutch.

Upon the death of Mr. Kessler in 1900 the directors made Henri Deterding his successor, and he moved to London and The Hague. In 1903 he made his most important merger—a marketing agreement with Shell Transport and Trading Company and the Rothschild bank in Paris, which held Russian oil lands, whereby the three formed Asiatic Petroleum Company. In 1907 they formed Bataafsche Petroleum Maatschappij to take over production, and Anglo-Saxon Petroleum Company to take over transport, storage, and distribution with Shell and Royal Dutch holding 40 percent and 60 percent respectively. Royal Dutch had been capitalized at about $100,000 when he joined it in 1890—the combined capital of the two new concerns was about $150,000,000.

Under Sir Henri, the Royal Dutch-Shell interests became firmly entrenched in many European and Asiatic markets and even established for itself a position in the first rank of producers, refiners and distributors in the United States particularly in the Mid-Continent and Pacific Coast areas.

During the World War he was active in maintaining oil supplies for the Allies and originated the idea of carrying oil in the double bottoms of passenger and cargo vessels.

Sir Henri was knighted by the British, getting a K.C.B. from Lloyd George just after the World War—although he retained his Netherlands citizenship.

Since the War he had become a bitter critic of the Soviet Government as a result of fundamental opposition to communist ideology. His sympathy with the present German government grew out of his appreciation of its opposition to the encroachments of Communism in Western Europe. He took an active part in providing food for starving Germans during a winter of shortage and cold.

His pipe was Sir Henri's constant companion, and he was rarely without it.

Upon his retirement from direction of the Royal Dutch-Shell interests in 1937, which by that time embraced some 200 companies and 40,000 employees, Sir Henri possessed a personal fortune estimated variously between $150,000,000 and $200,000,000.

Although a Netherlander by birth, Sir Henri Deterding spent much of his time in England and maintained a great estate at Melton Mowbray, where he rode to hounds for years. In the winter he was to be found skiing and skating at St. Moritz, and was an expert at both sports.

The family of Sir Henri took the body of the great oil man back to his estate at Dobbin, Mecklenburg, Germany, for burial.

His two sons came from England to join Lady Deterding who, friends said, is expecting the birth of a child next month. Sir Henri also is survived by a daughter by his first marriage and two daughters by his second. He married his third wife in 1936. She was formerly his secretary, Charlotte Minna Knaack, 38 years old, a German, who had been one of his most influential advisers, particularly in foreign affairs.

Foreign Oil Legion

EUGENE HOUDRY, president of Houdry Process Corporation, Philadelphia, sailed for France on board the CHAMPLAIN January 28th, accompanied by Mrs. Houdry and an associate, PIERRE M. QUILLERET, on a combined business and pleasure trip. Also on board was DR. W. F. FARAGHER, vacationing. Mr. Houdry will be surveying the possibility of applying his revolutionary system to certain French refineries.

Shortly after Mr. Houdry's departure the corporation announced that it had sold a license to Standard Oil Company of California to use the Houdry catalytic refining process, and the California company is starting operations at once of the application of the new methods to California crudes.

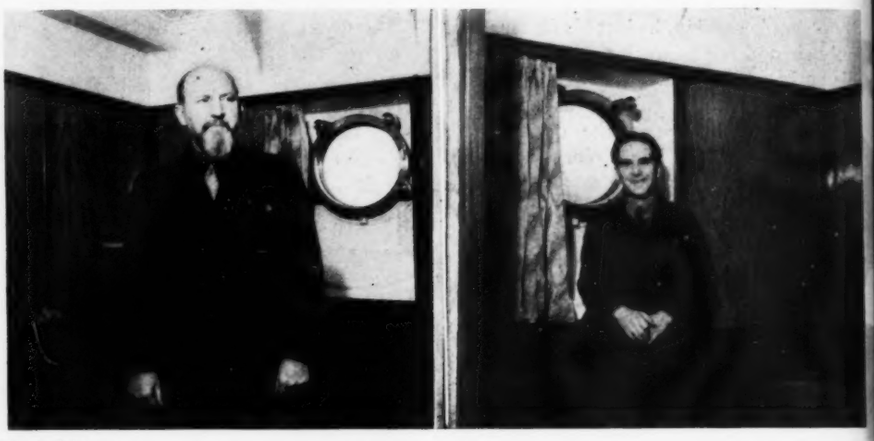
These catalytic processes are used for production of high octane motor gasoline and aviation fuels. The Houdry process, which has been the subject of keen interest throughout the oil industry for several years, was first explained in detail to the industry at the A.P.I. convention in Chicago last November (see WORLD PETROLEUM, Annual Refinery Issue, October, 1938).

W.P. Staff Photo

Eugene Houdry, originator of the Houdry catalytic refining process, in his cabin on the Champlain.

Under the licensing agreement California Standard obtains rights to operate under all Houdry patents, present and future. It includes both gas polymerization and catalytic treatment of motor and aviation fuels.

H. L. J. HUNTER, drilling superintendent at Anglo-Iranian Oil Company Ltd.'s Naft Khaneh oilfield, has been visiting the United States. He left Los Angeles for Dallas and the Mid-Continent by plane in mid-January, and is sailing from New York early in February.



W.P. Staff Photos

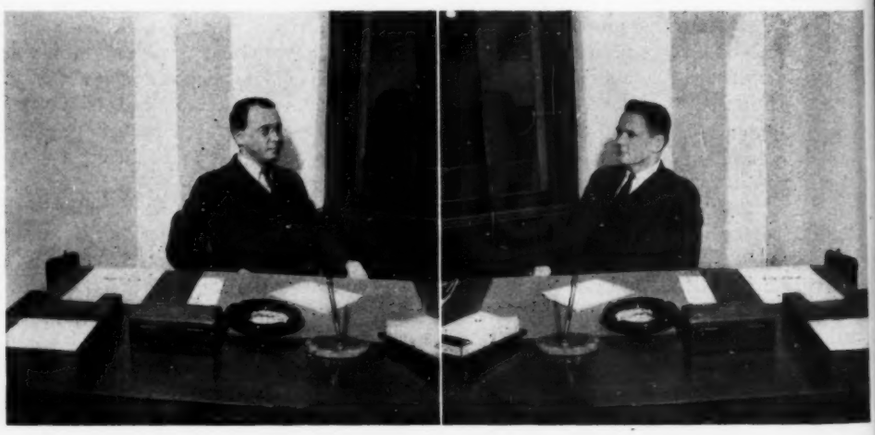
Russell Palmer, publisher, and Dick Wray, Hollywood movie consultant, as they left New York on board the Ile de France.

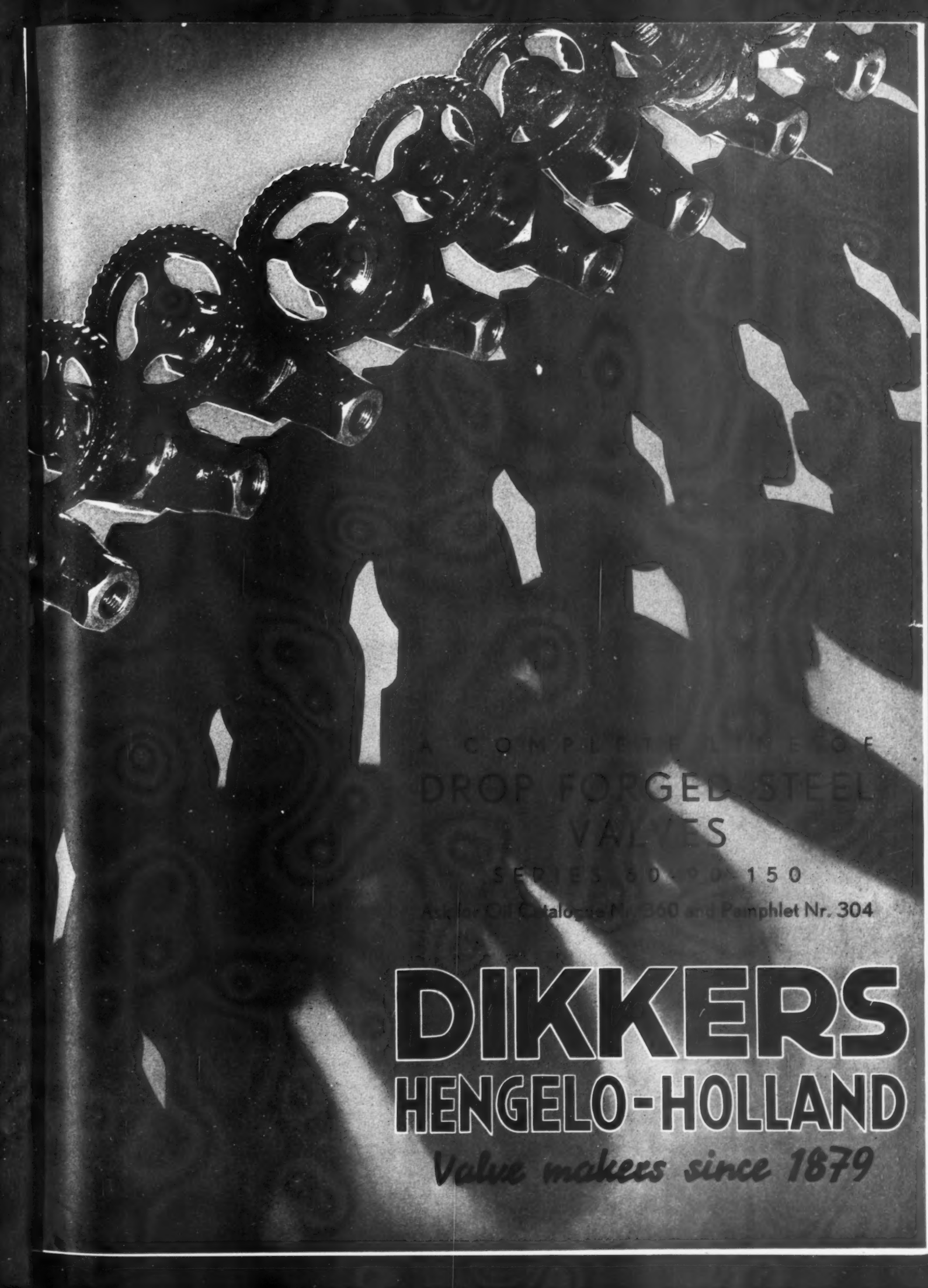
RUSSELL PALMER, newspaper man, world traveller, and publisher of WORLD PETROLEUM and other oil trade journals, left New York January 21st en route to London where he will show his natural color process film "Defenders of the Faith" for the first time in England since the addition of the sound track. Mr. Palmer resided in Spain several years and was a close student of the social, political and economic factors that ultimately led to the war. With this background he travelled to all parts of Nationalist Spain and was in the front lines at many of the most important engagements of the war. The highlights of his experiences and observations are recorded in this film.

EUGENE HOLMAN, president of All Foreign Producing Company, subsidiary of Jersey Standard, sailed from New York for Europe on board the liner WASHINGTON January 18th.

H. Robert Swanson (left) and John S. Wallis (right), well-known petroleum engineers, who are acting in a consulting capacity on a number of important refinery jobs, commenting on the unusual public interest in catalytic cracking, referred to this as indicative of the transition of the Petroleum Industry into a Chemical Industry. Said Mr. Swanson: "The use of a catalyst commercially in the cracking operation, which is the outstanding research development in Petroleum Technology during the past ten years, marks the evolution of this operation from a relatively uncontrollable, destructive pyrolysis into a defined reaction with control of the resultant products." Mr. Wallis and Mr. Swanson, under the corporate name, Petro-Chem Development Company, make their headquarters at 120 East 41st Street, New York. Their work consists principally of application of new and novel process and mechanical developments in the refining branch.

W.P. Staff Photo

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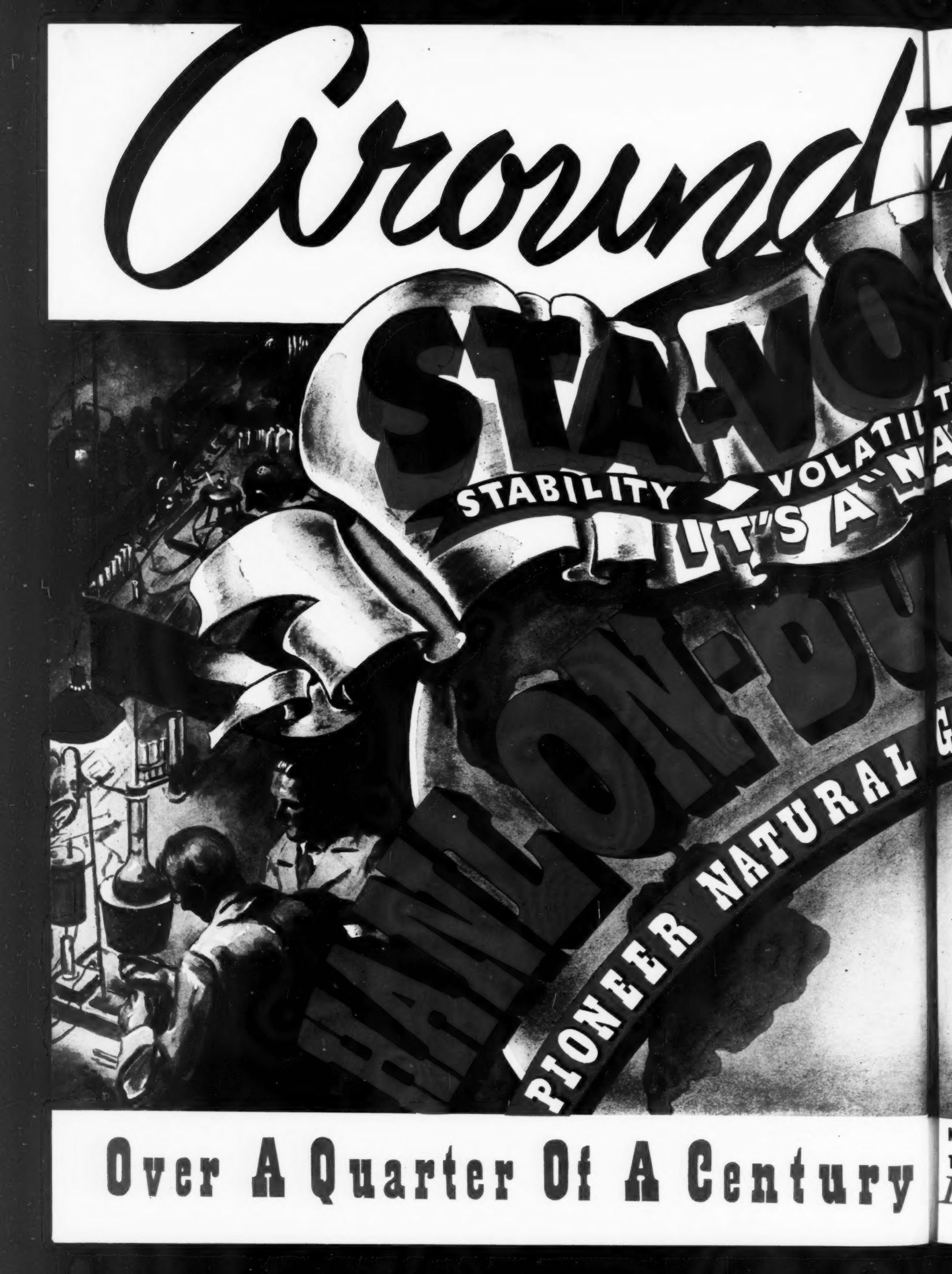
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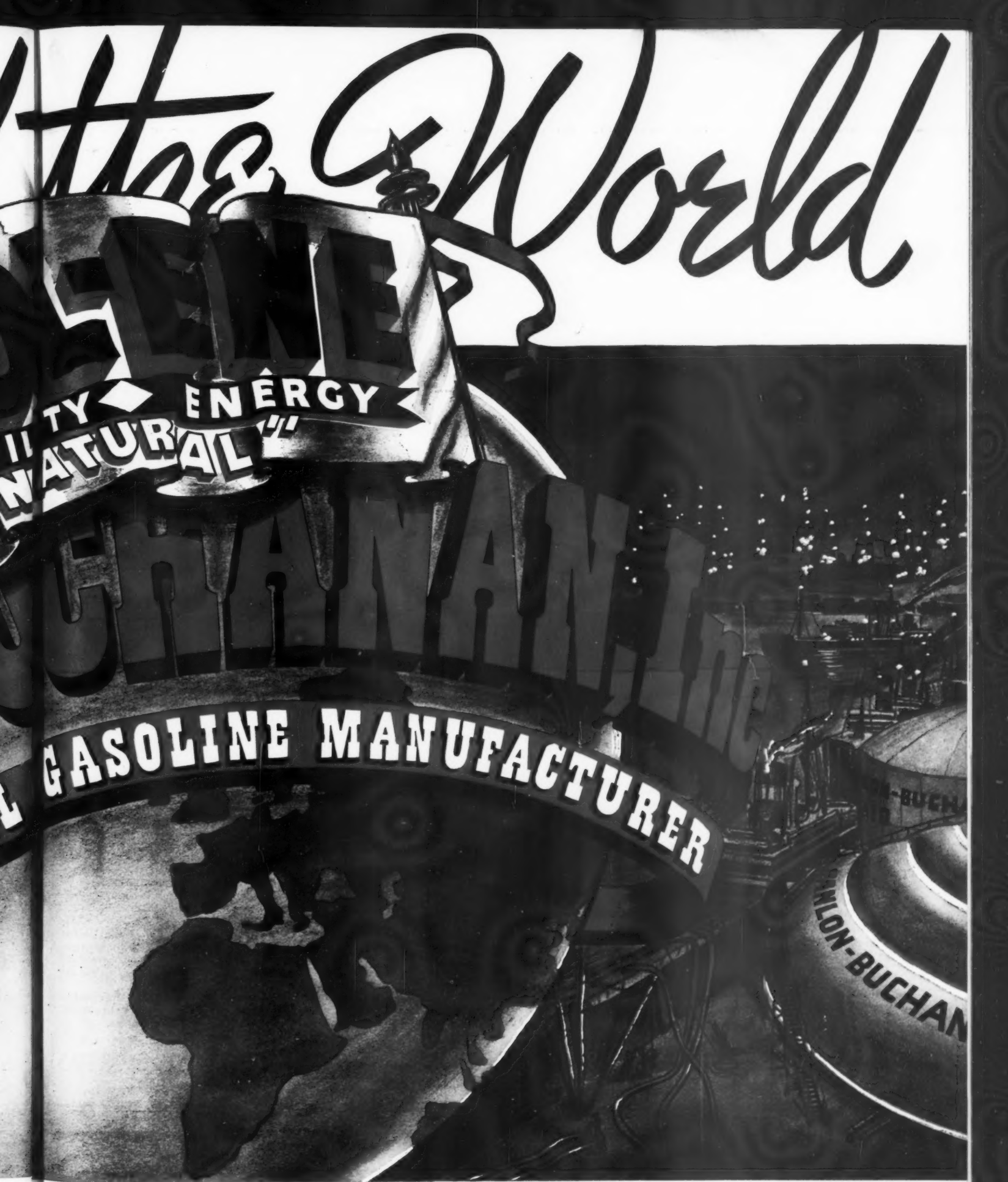

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PROBABLY no other region in the world has been invaded and re-invaded as often as Syria. History shows that almost twenty-seven hundred years ago King Sennacherib marched his conquering hordes over this desert country, sweeping everything before him. Then followed Nebuchadnezzar, King of Babylon . . . Xerxes, King of Persia . . . Alexander the Great, from Macedonia . . . the legionaries of Rome . . . the Mongolian hordes of Ghengis Khan . . . the Crusaders of Richard the Lion Hearted . . . and, even in recent times, the armies of the Turkish Empire. Thus, for thousands of years Syria's history has been but one invasion after another until even its largest city, Damascus, has become world famed for its fine steel swords!

But today it's an invasion of *industry* that is taking place in Syria, transforming its deserts into productive lands. Only recently one of the world's great engineering feats—the Kirkuk to Tripoli pipe line—was laid across Syria's hot sands, bringing the black wealth of neighboring Iraq almost six hundred miles to shipping ports on the Mediterranean.

Now, spurred by the outstanding success of the oilfields of neighboring Iraq, Syria is having an oil prospecting boom of its own. Operators are probing down into the desert in various parts of Syria—notably in the Jezireh district—in search of the oil geologists say is there.

And these operators are up against a tough proposition. Transportation is difficult—in many places the roads being continually wiped out by shifting sands—and, in addition, the scarcity of water makes it almost as valuable as the oil itself. Confronted with these obstacles, the operators can't afford to take chances. That's why in Syria you will find the Johnston Formation Tester ready to save development dollars on these exploratory wells.

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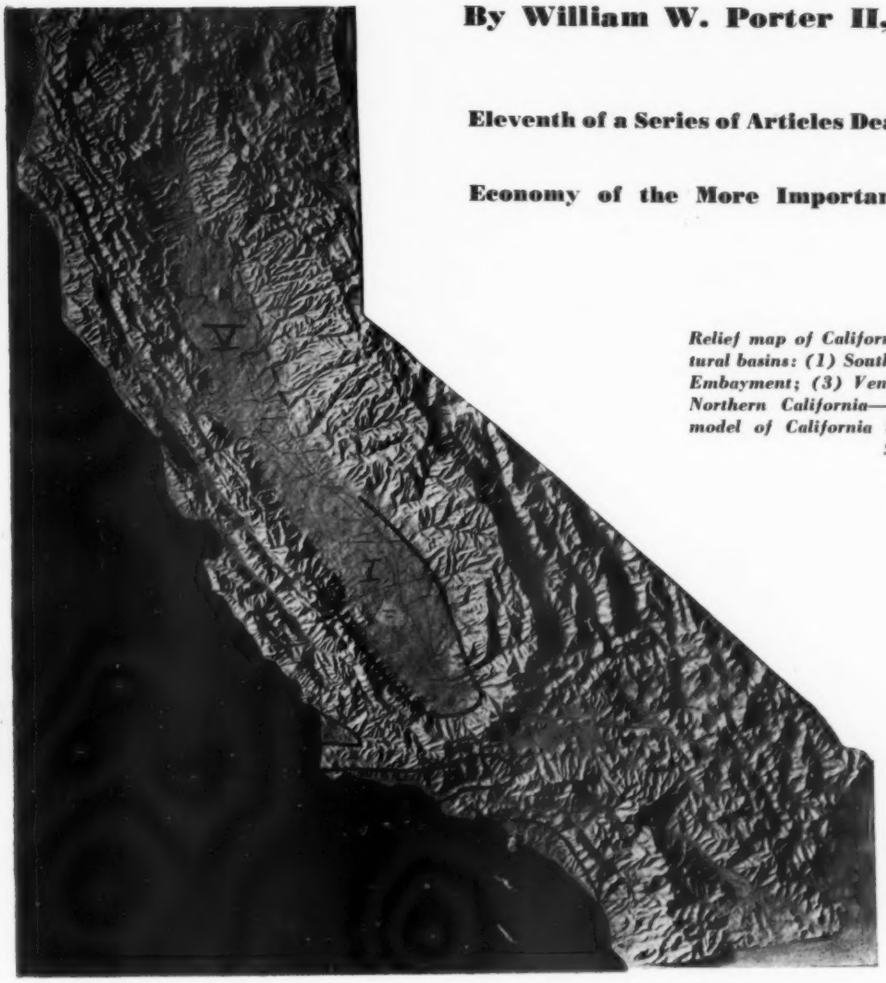
GEOLOGY AND ECONOMIC SIGNIFICANCE
of California's 1935-1938 Oil Discoveries

By William W. Porter II, Consulting Geologist

Eleventh of a Series of Articles Dealing With the Geology, Reserves and Economy of the More Important Oilfields Throughout the World.



Relief map of California showing principal oil-containing structural basins: (1) Southern San Joaquin Valley; (2) Santa Maria Embayment; (3) Ventura Basin; (4) Los Angeles Basin; (5) Northern California—Relief map from photograph of relief model of California by N. F. Drake, geological department, Stanford University.

OUTSTANDING as a major discovery era in California oil history is the period from 1935 to the present. During this period 16 important oilfields with total reserves of approximately 1,500,000,000 bbl. of oil were discovered. Several other minor discoveries were made, as well as establishment of extensions and deeper zones in previously proven fields, but only important new developments will be considered in this article.

For several years prior to 1936, the state annually consumed more oil than was discovered and the ratio between known reserves and demand was steadily declining. With the exception of Mountain View, no major discoveries had been made in California since Kettleman Hills and Elwood were located in 1928. From the early part of 1935, the coincidental factors of improved and successful seismograph instruments and executive recognition of the necessity of newer and more costly discovery methods resulted in a campaign of exploration which has added many square miles to the category of lands likely to contain oilfields, and which has materially increased stratigraphic potentialities.

In an attempt to crystallize the effects of this discovery wave, this article will first treat briefly the individual new fields and will then consider the scientific significance and the economic effects related to markets, proration, reserves, excessive drilling and similar matters.

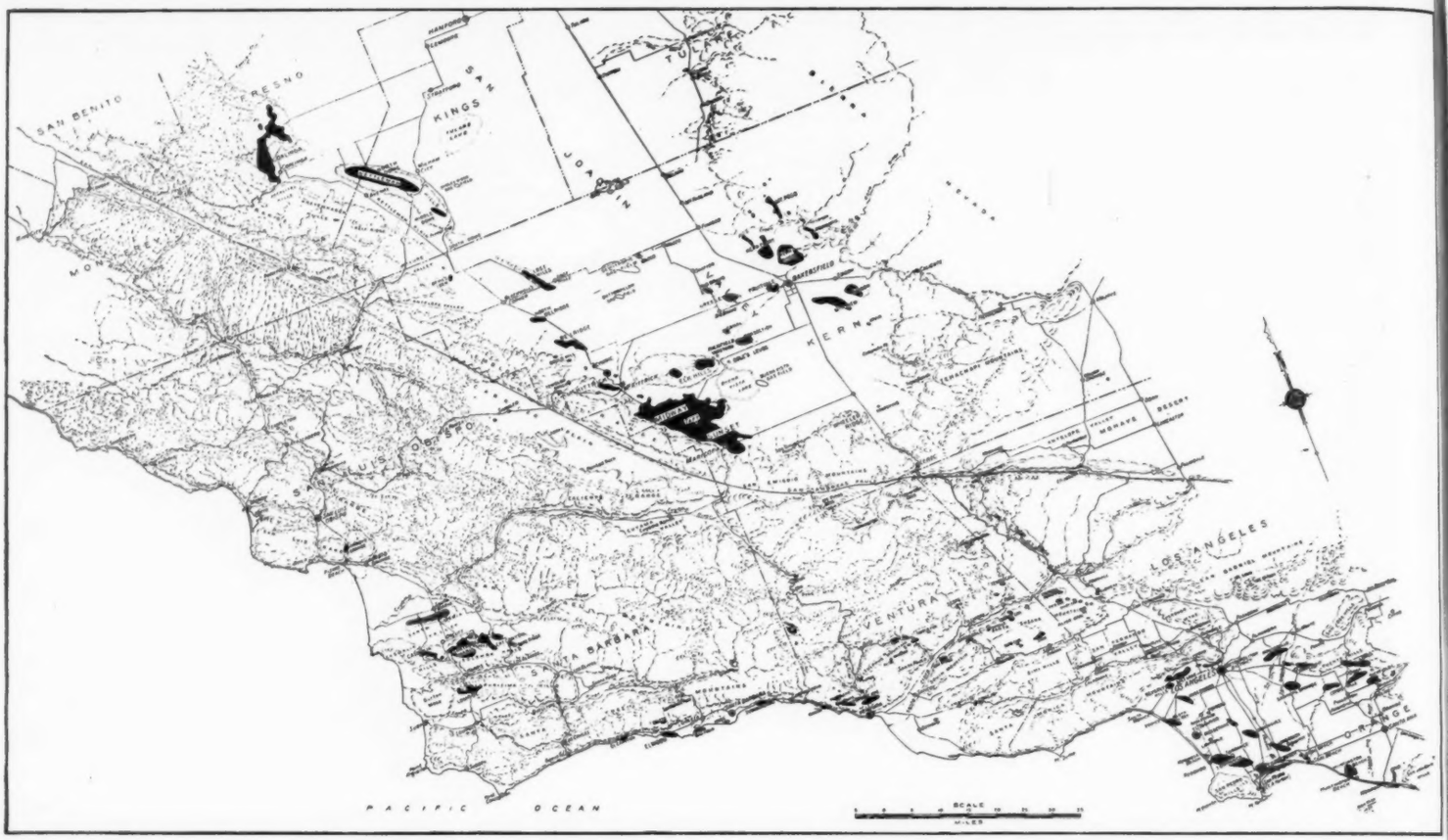
All of the important oil production in California is obtained from four structural basins in which great thicknesses of sedimentary rocks have been downwarped as a whole and then folded and faulted into numerous individual structural traps which underlie the oilfields of the state. These structural basins are the Los Angeles Basin, the Ventura Basin, the Santa Maria Embayment and the San Joaquin Valley. Within the last three years, major discoveries have been made in all four of these structural basins. A fifth district currently attaining prominence is Northern California.

SAN JOAQUIN

In the central part of the southern San Joaquin Valley the stratigraphic section is in general similar in all the fields although it varies considerably in detail, and the minor variations are of great economic importance.

Loosely consolidated sands of the Tulare formation, generally considered Pleistocene in age, are found from the surface to approximately 1,000 ft. Below the Tulare beds occur up to 6,000 to 8,000 ft. of siltstone, claystone and sands of Pliocene age. These beds are equivalent to formations known locally elsewhere as Jacalitos, Etchegoin and San Joaquin clay. The base of the Pliocene is found at depths varying from about 7,100 ft. in the Ten Section area to 8,440 ft. at Wasco.

The brown shale of the Upper Miocene underlies the Pliocene. It consists of approximately 900 ft. of brown shale. The brown shale is underlain in the Ten Section-Greeley area by 1,200 to 1,400 ft. of beds composed predominantly of sand with alter-



Topographic map of California oil and gas fields, with additions by the author, reproduced through courtesy of E. H. Noble, chief geologist, Union Oil Company of California. The fields discussed in this article are indicated in red.

nating thin beds of shale and siltstone. This sand zone is known as the Greeley zone, Ten Section zone, and Stevens zone. It is productive at Ten Section, Canal, Cole's Levee, Richfield Western and Greeley. The beds composing the Stevens zone are near-shore deposits of the type that grade laterally into offshore deposits of shale. The sand of the Ten Section area becomes more silty and, consequently, is less productive in the Greeley area. Since the Upper Miocene shoreline was to the southeast and east of these oilfields, the nearshore sand deposits grade laterally to shale toward the north. The sudden disappearance of the Greeley zone between Greeley and Rio Bravo strongly suggests a delta type of sedimentation. At Rio Bravo, the Stevens zone is missing, its place being taken by offshore deposits of shale equivalent in time of deposition to the sands of the Stevens zone. The sands of the Stevens zone at Ten Section are fairly well cemented medium to occasionally coarse-grained. Porosity is reported to vary from 12 to 30 percent and average about 22 percent. The porosity decreases to the north, as the sands disappear.

The Upper Miocene in the central part of the Valley is approximately 3,000 ft. thick, except in areas such as Ten Section-Greeley, where sand lenses such as the Stevens zone occur. In such localities, the thickness of the Upper Miocene is increased by the amount of the additional thickness of the sand lenses. The Temblor, in the central part of the Valley consists of approximately 2,500 ft. of hard, dark gray shale streaked with hard sand and siltstone. Many geologists place the Temblor in the Lower Miocene—others consider it Middle Miocene. The prolific Rio Bravo sand is the particularly prominent sand member in the lower Temblor. The Rio Bravo sand is a porous, cleanly-washed sand apparently well saturated with oil within field limits. It is suspected to be equivalent to the Vedder sand, which is productive along the east side of the Valley. Below the Miocene occasionally occurs approximately 1,000 ft. of hard, dark shale of Oligocene age and below the Oligocene occur Eocene beds of a thickness not yet penetrated in the central part of the Valley. To the east, Eocene and Miocene are progressively underlain by granite. As the Avenal sand, the producing horizon of the Kettleman Hills deep zone and its probable equivalent at East Coalinga are in the Eocene and within reach of the drill, the Eocene will be significant in future exploration on the Valley floor.

The important discoveries in the San Joaquin Valley with the exception of East Coalinga, are in the flat central part of the Valley floor where no surface geological information is available, except perhaps in a few cases vague topographic suggestions. Most of the fields were discovered by geological interpretations of the results obtained from surveys with reflection seismograph.

Ten Section

Ten Section Field was discovered by Shell Oil Company June 2nd, 1936, when Stevens No. 1 (K.C.L. A-1-29) was put on production after reaching a total depth of 7,888 ft. The field is located in Township 30 S., Ranges 25 and 26-E, M.D.B. & M., Kern County, California, about 12 mi. southwest of Bakersfield. Since the discovery nearly three dozen producing oil wells have been completed whose initial productions average approximately 3,000 bbl. daily, 33 deg. A.P.I. clean oil, with 2,000,000 to 3,000,000 cu. ft. of gas.

The discovery well produced approximately 800 to 1,000 bbl. daily of 61 deg. A.P.I. clean oil with about 13,656,000 cu.

ft. of gas through a half-inch bean with tubing pressure of about 1,950 lb. and casing pressure of about 2,330 lb. The well was killed in March, 1937 and deepened to 8,240 ft. In April, well flowed at 3,864 bbl. daily rate making 3,400,000 cu. ft. of gas. Completions at greater depth led to production of 31 to 35 deg. oil.

Most of the wells produce from about 300 ft. of zone, which contains about 75 percent oil sand. Developments indicate that about 1,800 acres are proven. It is interesting that of 27 producing wells, 20 were either bottomed or plugged to within 25 ft. of a total depth of 8,220 ft.

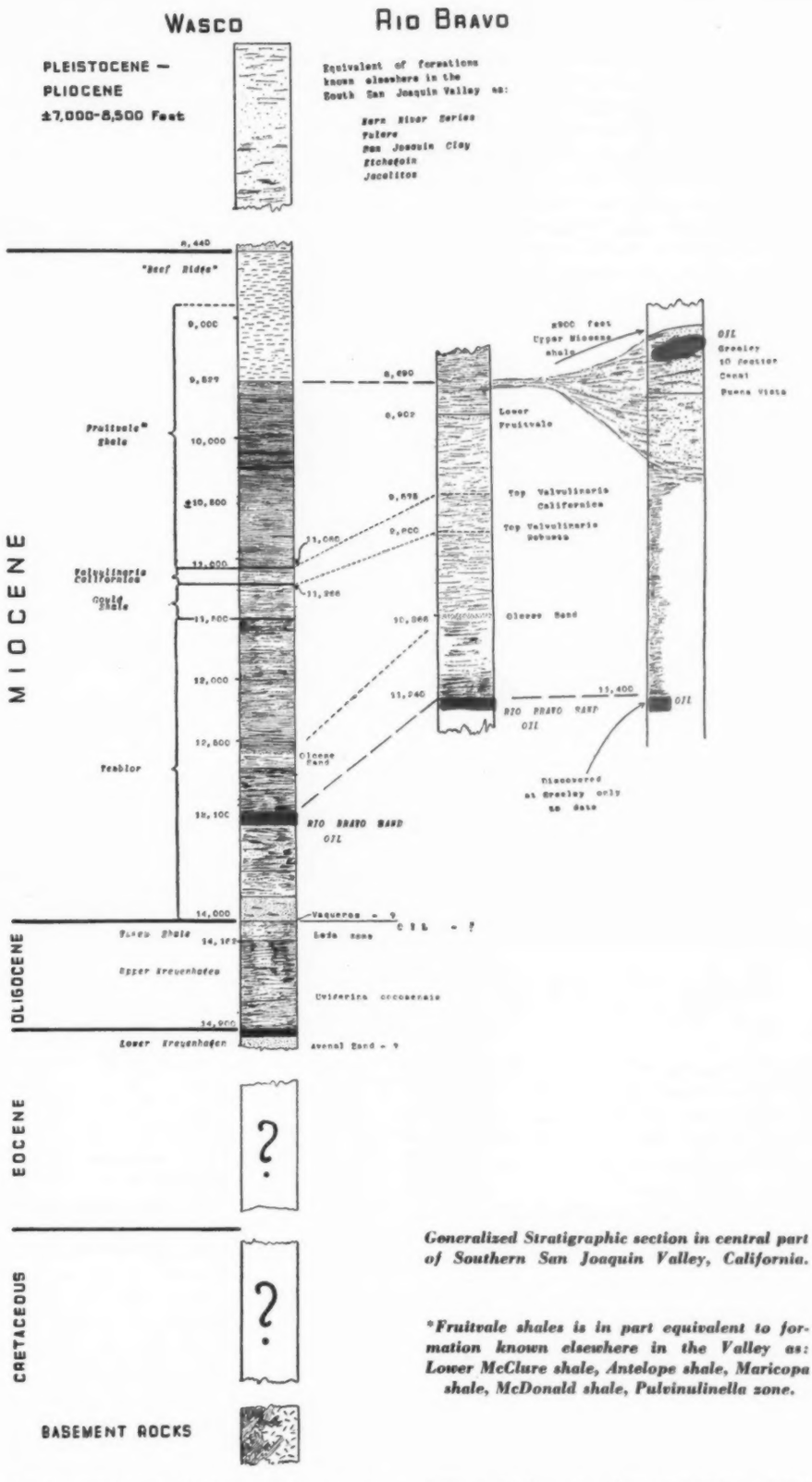
The entire field is operated by Shell Oil Company and the entire landowner's interest is owned by Kern County Land Company, so the field is an instance where development may proceed on a scientific basis without detriment to either operator or royalty owner. Complications may be introduced by varying percentage of royalty payable on different portions.

The usual casing program is to set seven-inch at the top of the production zone at depths of 7,900 to 8,000 ft. Five-inch liners are hung through the oil zone. Aluminum liners are used in outpost wells, and steel liners within the field. In the gas cap area the liners are left blank opposite the gas zone, and cemented through perforations at the bottom of the gas. Surface pipe, usually 11¾ in., is set at about 1,000 ft.

Gas-oil ratios have been kept down to 700 cu. ft. per bbl., and bottom hole pressures which are approximately 3,500 lb. per sq. in. show no appreciable decline yet. The gas is treated at the field in the Shell Company's 15,000,000 cu. ft. per day natural gasoline plant.

The field produced 188,464 bbl. of oil in 1936, 932,427 bbl. in 1937, and 2,472,779 bbl. during 1938, or a total from discovery to January 1st, 1939, of 3,593,670 bbl. Production is currently (January, 1939) about 8,200 bbl. per day.

Derricks are skidded from location to location, and the 8,200 ft. wells are often completed in 40 days total elapsed time from commencement of rigging up to placing well on production.



Generalized Stratigraphic section in central part of Southern San Joaquin Valley, California.

**Fruitvale shales is in part equivalent to formation known elsewhere in the Valley as: Lower McClure shale, Antelope shale, Maricopa shale, McDonald shale, Pulvinulinella zone.*

Canal

The Canal Field was discovered in November, 1937, by Ohio Oil Company in Well K.C.L. E-3, on property owned by the Kern County Land Company. Initial production was 2,267 bbl. daily of 37.5 deg. A.P.I. oil, 17,000,000 cu ft. of gas through a one-inch bean, tubing pressure 420 lb., casing pressure 1,525 lb.; from about 75 ft. of oil zone. Total depth of the well is 8,175 ft.

The field is about two miles northwest of, and in many ways is similar to, Ten Section Field. Producing depths are approximately the same and both fields produce from the Stevens zone, although there may be some question as to the identification of individual sand bodies. Wells have initial production of 2,000 to 3,500 bbl. daily, about 35 deg. A.P.I. oil with 1,000,000 to 2,000,000 cu. ft. of gas. Gas-oil ratios as the wells are produced are about 400 to 700 cu. ft. per bbl. There is no surface

indication of structure and field was discovered by geological interpretation of reflection seismograph profiles.

As of January, 1939, there were 15 producing wells in the field, all on Kern County Land Company property but with the lease ownership divided between Ohio Oil Company with seven wells and Shell Oil Company with eight wells. Eighty acres owned in fee by the Standard Oil Company may be productive, but otherwise the field will have to be exceptionally large to fall outside of leases held by Ohio and Shell. About 800 acres can be considered proven. Wells are bottomed at about 8,350 ft. and are being drilled in about 45-65 days elapsed time from commencement of rigging up to placing on production.

Production for the last few weeks of 1937 was 31,575 bbl. and for 1938 was 849,154 bbl., making total production from discovery to January 1st, 1939, of 880,729 bbl.

Greeley

Standard Oil Company discovered the Greeley Field in Well K.C.L. 11-1, in December, 1936. The well was bottomed at 7,807 ft. and initial production from about 65 ft. of oil zone was 2,712 bbl. daily. On potential test the well made 2,657 bbl. daily of 36.7 deg. A.P.I. clean oil and 2,336,000 cu. ft. of gas through a 1½ in. bean.

The field consists of approximately 1,500 acres. Most of the proven acreage is controlled by Standard Oil Company leases from Kern County Land Company, although a few smaller tracts also leased by Standard are in the field. Formations penetrated are similar to those encountered in the Ten Section-Canal area and production occurs in the upper part of the Stevens zone.

From discovery in December, 1936, to January, 1937, Greeley production was 531,604 bbl., and for 1938 was 1,163,873 bbl., with total production from discovery to January 1st, 1939, 1,695,477 bbl.

RIO BRAVO SAND—The most significant development at Greeley took place in June, 1938, when the Standard Oil Company well, K.C.L. 11-2, discovered the Rio Bravo sand below the Stevens zone. The top of the Rio Bravo sand was discovered at 11,419 ft.; total depth 11,520 ft.; 6⅝ in. casing cemented at 11,396 ft. From 124 ft. of producing zone, the well produced about 15,000 bbl. daily of 35.1 deg. A.P.I. oil with 15,000,000 cu. ft.of gas, through a 16/64 in. bean, with 1½ in. and one inch casing beans, tubing pressure 1,200 lb. and casing pressure 770 lb. Although production has been reduced to a nominal amount under proration, the discovery is of great significance as indicating a new reserve which may at least treble the ultimate production of the Greeley field.

The second test of the Rio Bravo sand, Superior Oil Company's Krause No. 1 was abandoned in October, 1938, after drilling to 12,504 ft. The Rio Bravo sand which was reported tapped at 11,495 ft., was wet.

The third well in the field to drill to the Rio Bravo sand is Standard Oil Company's Fleishauer No. 3—2 which cored oil sand.

The entire producing area, in which there are 18 wells, is under lease to Standard Oil Company.

Rio Bravo

In November, 1937, Union Oil Company completed Kernco (K.C.L.) 1-34, in the Miocene Rio Bravo sand, at a total depth of 11,302 ft.; 4¾ in. casing was cemented at 11,220 ft. and well brought in without liner for 1,025 bbl. daily, 39.5 deg. A.P.I. oil and about 1,300,000 to 2,000,000 cu. ft. of gas through a 7/64 in. bean; tubing pressure 1,970 lb., casing pressure, 2,040 lb.

Although the well has a potential of about 6,000 bbl. daily, it has been estimated that on open flow the well would produce 10,000 to 20,000 bbl. daily. The Rio Bravo sand is probably equivalent to the Vedder sand, which is productive on the east side of the Valley. For five months, K.C.L. 1-34 held the record as the world's deepest producing oil well.

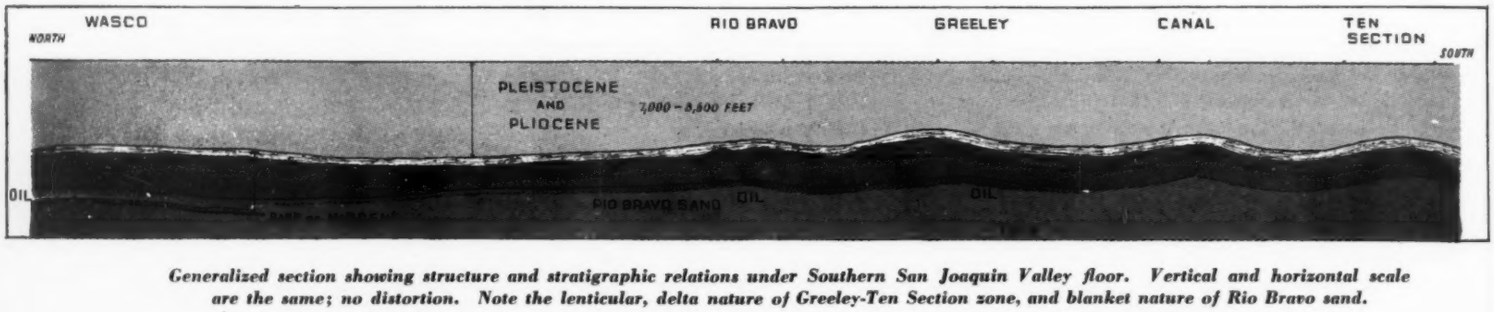
The 24 producing wells in the field in January, 1939, have an aggregate potential of 132,880 bbl. per day. Of these wells, six were drilled by Union Oil Company, 11 by Superior Oil Company, three by Geo. F. Getty, Inc., and four by General Petroleum Corporation. For the few weeks from discovery to January 1st, 1938, the field (one well) produced 127,834 bbl. Production for 1938 was 1,944,578 bbl., making a total production from discovery to January 1st, 1939, of 2,072,412 bbl. The effect of the rapid development of this deep pool during the latter half of 1938 is indicated by the production figures. Total field production to July 1st, 1938, was only 609,774 bbl., yet 1,462,638 bbl., nearly three-quarters of the field total, were produced in the last six months of 1938.

About 1,800 acres may be regarded as proved, on the basis of acreage above productive contours. All wells drilled to-date are on the southeast plunge, and structural closure exceeding 250 ft. is indicated by present development.

STRATIGRAPHY—Pleistocene and Pliocene strata which extended to a depth of about 7,600 ft. are similar to these formations elsewhere in the central part of the Valley. It is of interest that the Upper Miocene sand productive at Ten Section, Canal and Greeley is practically absent at Rio Bravo, being represented by a few thin stringers of brown siltstone. The 1,400 ft. sand lense in part productive at Greeley has practically pinched out to the northwest in a distance of three miles. More detailed information on the stratigraphy is shown in the columnar section reproduced on the preceeding page.

High bottom hole pressures up to 4,800 lb. per sq. in., no decline in producing pressures, high porosity (25 percent) and high permeability (200-300 millidarcys) the large acreage, and good oil sand thickness of 260 ft. all indicate that Rio Bravo is an outstanding major discovery.

The oil is 38 to 40 deg. A.P.I. It has a low sulphur content, high gasoline content of 45 percent, 33 percent gas oil, and 20 percent residuum. Octane rating of the straight run gasoline is approximately 58-60 by the A.S.T.M. motor method. Present gas/oil ratio is about 1,200 cu. ft.



Generalized section showing structure and stratigraphic relations under Southern San Joaquin Valley floor. Vertical and horizontal scale are the same; no distortion. Note the lenticular, delta nature of Greeley-Ten Section zone, and blanket nature of Rio Bravo sand.

per barrel. Bottom hole temperature is 250 deg. F.

Wasco

The Wasco field has had a great deal of publicity because of the rather amazing record of the discovery well. It was the world's first 13,000 ft. well, the world's first 14,000 ft. well and the world's first 15,000 ft. well, the deepest well in the world with total depth of 15,004 ft. and the deepest producing oil well in the world, when it flowed at 3,000 bbl. per day rate through a ¾ in. bean from formations opposite perforations in the liner at 13,092 to 13,175 ft. The well was swabbed in April 11th, 1938, and produced about 3,000 bbl. per day of 35 deg. A.P.I. oil. From discovery in April to Jan. 1st., 1939, the field produced 125,065 bbl. of oil. Little is known of the productivity of the structure, as sufficient wells have not yet been drilled to check the seismograph profiles, through the use of which the well was located.

As of January, 1939, there were only two producing wells in the field. These are Continental's KCL A-2, discovery well and deepest well in the world, and Standard's Mushrush No. 1.

The top of the Upper Miocene was encountered at about 8,440 ft. As is the case at Rio Bravo, a few miles to the south, the Ten Section-Greeley production zone is missing and production was obtained from the Rio Bravo sand which showed good porosity, permeability and saturation in its upper part near 13,000 ft.

Deeper production from the Oligocene is a possibility that has not yet been tested. Opposite the Oligocene zone from 14,049 to 14,315 ft., a perforated liner was placed; these perforations are separated from the present producing string by cement outside the liner and a concrete baffle inside the liner. As all fittings above are drillable aluminum, this zone is in condition to be tested when necessary. Successful completion in the shallow (13,000 ft.) zone has thus far prevented a deep test. The significance of the achievement has been written about in numerous periodicals and the mechanical, engineering, and geological features are not to be minimized.

East Coalinga

In June, 1938, the East Coalinga Eocene Pool was discovered through a project financed half by Petroleum Securities Company, one-fourth by Honolulu Oil Corporation and one-fourth by Seaboard Oil Corporation. The discovery well, now known as No. 1-18-F, reached the top of the Eocene oil zone at approximately 5,950 ft. below sea-level and with about 100 ft. of penetration, showed a production rate indicating discovery of a 15,000 bbl. well. Because of limited tankage and the policy of abiding by proration, the well never actually produced 15,000 bbl. in 24 hr., although it is generally conceded by those familiar with the operation that the discovery may be rated as a 15,000 bbl. well.

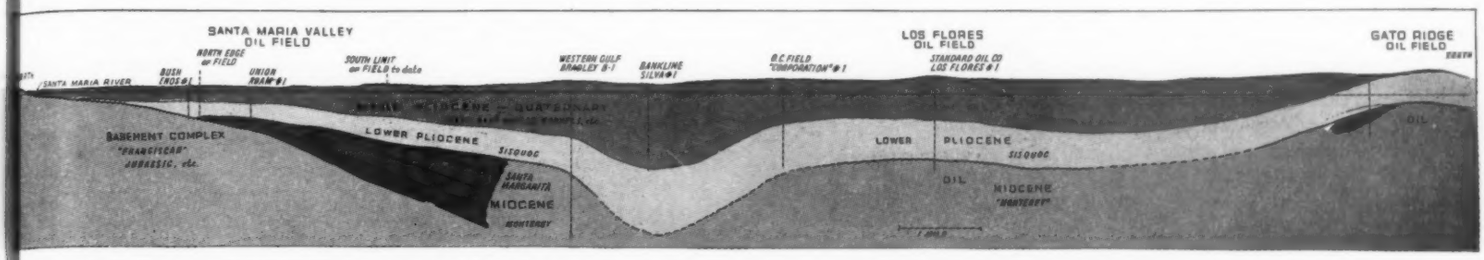
No other wells were completed in the field until after September 1st, 1938, but since sustained development is being carried on, it is now apparent that a major oilfield has been discovered. The producing sand is of Eocene age, and although probably equivalent to the Avenal sand of Kettleman Hills, it is known in the East Coalinga area as the Gatchell sand. In the productive area this sand is known to be at least 326 ft. thick and yet in less than a quarter of a mile to the west, it is entirely absent. Locations at which the Gatchell sand is absent are higher structurally than the several producing wells and the western (structurally higher) area is non-productive entirely because of stratigraphic complications. Although structure, of course, is obviously a factor which determines what portions of the Gatchell shall be productive, nevertheless the up-structure limit to production definitely classifies the field as being what is generally known as a stratigraphic type. The continuity of stratigraphic horizons other than the oil sand such as, for example, the Kreyenhagen shale, and the 20 ft. Glauconite sand, the top of which occurs approximately 100 ft. above the top of the Gatchell sand, precludes the possibility that the up-structure limit of production is due to faulting.

Below the usual Miocene section of the Coalinga field occurs about 1,050 ft. of Kreyenhagen shale of probably Oligocene age. The Kreyenhagen is encountered at depth of approximately 4,500 ft.-4,769 ft. in the discovery well. Below the Kreyenhagen shale occur Eocene beds, one of which is the Gatchell sand. The top of this zone was encountered at 5,942 ft. below sea-level in the discovery well. Whether or not the rapid disappearance of the oil sand within a few hundred feet may be due to shore line conditions or to perhaps the configuration of an Eocene delta, enough is known to indicate that the extent of the Gatchell oil sand has been determined by the peculiarities of Eocene sedimentation.

A high structural relief of productivity of 1,450 ft. has already been indicated by the down-structure productivity of Superior Oil Company well, Hight No. 1.

Because of the newness of the discovery and, consequently, the lack of pertinent information, it is impossible at the present time to discuss the geology adequately although it is apparent that a major oilfield has been discovered. The field is rated as a new discovery because the stratigraphic control over the productive limits set it apart as something more than just another deep sand in an old oilfield.

The Gatchell sand is a fairly coarse granitic sand having high porosities averaging perhaps 25 percent, but with some determinations as high as 32 percent. A number of tests indicate that the permeability in millidarcys ranges from 523 to above 2,000, with an average of probably 700 to 1,000. The maximum oil sand thickness exceeds 550 ft.



Structure diagram from north bank of Santa Maria River southerly through Santa Maria Valley, Los Flores, and Gato Ridge oilfields. The section is diagrammatic only and does not show several known or suspected faults. Vertical and horizontal scales are the same; no distortion.

East Coalinga Geological Section

	Approximate thickness
Etchegoin, gravels, sands, clays	3,000 plus
Miocene "Brown shale"— Santa Margarita	800
Temblor (Miocene)	1,050
Kreyenhagen (Oligocene)	1,050
Canoas Silt	16
Green Sand	20
Turritella Silt	70-90
Tight Sand	20
Gatchell Oil Sand (Eocene)	0-550+
Arroyo Hondo Siltstone (Eocene)	

East Elk Hills

The Elk Hills uplift extends eastward for a considerable distance beyond the obvious topographic expression of the Elk Hills proper. The plunging structure is pointed in the general direction of the Ten Section oilfield. Two significant wells, Richfield Oil Corporation's Tupman-Western No. 1, and Ohio Oil Company's K.C.L. F-1 were drilled on the generalized easterly plunge of the Elk Hills uplift. The wells are about three miles apart and minor structural irregularities will probably indicate that in a strict sense, they are on different folds. Both wells encountered sands of the Ten Section zone and at both places the sands contained oil. The east Elk Hills plunge is thus known to be at least partially blanketed by the Ten Section zone. The presence of oil in the Ohio well, and of high gas content and high gravity oil (53 deg. A.P.I.) in the higher structurally Richfield well indicates some kind of trap up-plunge from the locations. Whether the oil is trapped on the plunge by structural or stratigraphic features is not yet known. Some characteristics of the Ten Section-Greeley zone suggest that it is a delta type of deposit formed by rivers flowing into the Upper Miocene sea from the east. If such should be the case, the zone would logically be expected to pinch out to the west. Geological conditions indicated by these wells, and the known productivity of the zone elsewhere, suggest discoveries of major importance.

Cole's Levee

The first oil well on the East Elk Hills plunge was brought in on November 11th, 1938, by Ohio Oil Company and is known as K.C.L. F-1. The new field was named Cole's Levee. With bottom at 9,365 ft. and seven inch casing cemented at 9,220 ft. a liner was run and the well completed flowing at a 730 bbl. per day rate, 44.5 deg. oil and 3,900,000,000 cu. ft. through a 48/64 inch bean with 470 lb. tubing pressure and 900 lb. casing pressure. Within a few days it established a potential of 884 bbl. per day, 44 deg. oil, 0.5 percent cut, through two ¾ inch beans; tubing pressure 321 lb., and casing pressure 850 lb. When the bean was reduced to 4/64 to prorate production to 208 bbl. per day and 580,000,000 cu. ft. gas, pressures rose to 2,500 lb. on the tubing and 2,800 lb. on the casing.

The well produced 10,345 bbl. of oil to January 1st, 1939, and was the only producing well in the field at that date. Ohio, Richfield, Standard, Union, and Tidewater Associated were either drilling or had announced locations in January, 1939.

Richfield Western

Richfield Western was discovered by Richfield Oil Corporation on November 27th, 1938, in well Western A No. 32-32 (formerly known as Tupman Western No. 1). With bottom at 8,677 ft. and 8⅝ inch casing cemented at 8,406 ft., and 280 ft. of perforated liner the well was originally completed at an initial rate of 3,752 bbl. per day of 44.1 deg. oil cutting 4.8 percent and 18,000,000,000 cu. ft. gas flowing through a 1½ inch bean with 1,000 lb. tubing pressure and 1,000 lb. casing pressure. The well was killed and a string of 6⅝ inch casing landed on bottom at 8,677 ft. and cemented through perforations at 8,523 ft. The lower 128 ft. was perforated. On January 4th, 1939, the well was recompleted, and on the first 24 hour gauge made 1,764 bbl. of 44.4 deg. oil cutting 0.1 percent and 7,060,000,000 cu. ft. gas through a 1½ inch bean, with 400 lb. tubing pressure and 1,350 lb. casing pressure. By the middle of January the bean was reduced to 1/64 inch to attain production of 307 bbl. per day. Pressures increased to 2,500 lb. on the tubing and 2,900 lb. on the casing, the gravity increased to 48.6 deg., and gas decreased to 1,888,000,000 cu. ft. per day.

The discovery comes as a result of the active exploration campaign initiated by Richfield Oil Corporation since termination of the receivership of the old Richfield Oil Company.

Gas Fields

Discoveries of gas in northern California are shown on the map on page 51. Of the fields shown, Marysville Buttes, Chowchilla, and Tracy were discovered prior to the period covered by this article. Another gas field in Humboldt County north of the top of the map was established in October 1938 by The Texas Company after redrilling Eureka No. 2 well to 4,864 ft. Production was slightly more than 500,000 cu. ft. per day.

It is curious that northern California structures produce gas rather than oil regardless of the geological age of the producing formation. The Pliocene (The Texas Company, Humboldt County), Eocene (McDonald Island and Rio Vista), and Cretaceous (Tracy and Willard Ranch), all produce gas and no oil yet. A small amount of high gravity condensate is produced at Rio Vista.

SANTA MARIA

The Santa Maria District is one of the oldest oil-producing districts in California, having produced considerable oil prior to 1900. Although the total volume of oil yet produced is small in comparison with the production of the other oil basins in California, the available potential reserves of heavy oil make this district of major importance.

There are about eight oilfields in the district, of which the Orcutt Field is outstanding in point of total production, which is to date about 135,000,000 bbl. The oil in reserve in this district will considerably surpass the total past production, as potential reserves from all fields will probably exceed 300,000,000 bbl.

Since 1935, three important areas have been developed. Of these, the Santa Maria Valley was discovered in 1936 and the Los Flores area in 1938. Although the Gato Ridge Field was discovered in 1931 by Barnsdall Oil Company, no wells other than the discovery well were drilled until after January 1st, 1936. Development prior to that time consisted of drilling the discovery well and its occasional, irregular production.

The discovery of large reserves in the Santa Maria district has more significance than would have the discovery of the same reserves elsewhere at more inaccessible geographic locations. Although at the present time the output of the entire district is but a fraction of even the Umpire's allowable because of the bottle-neck situation of the market outlet, there cannot help but be a future economic significance in the existence of this large reserve within a few miles of tidewater. The influence of the Santa Maria discoveries has been definitely felt in the asphalt and gasoline markets.

GEOLOGY—The area of the oilfields is a structural embayment extending from points on the Pacific Ocean inland for about 30 miles to the point of a V. Within this V are a number of minor folds, in connection with which occur the oilfields in which oil is produced from rocks of Lower Pliocene, Upper Miocene and Middle Miocene.

Important structural features of this basin are due to earth movements associated with the close of the Miocene period. During Upper Miocene time, a much larger area was submerged beneath the ocean but due to structural movements, uplifts occurred near the edges of the present structural basin. The effects of these movements was to elevate above sea-level the rocks lying outside the present structural basin leaving the central portion of the basin submerged. As a consequence, the basin is one whose rims were subject to erosion and whose central part was an area of continuous deposition from Miocene to Pliocene time. Because of this condition, the Pliocene beds lie conformably upon the Miocene in the depositional center and with marked unconformity at the basin edges. The oil occurrences are therefore due in some places to the unconformable overlap of Pliocene over previously eroded Miocene and, in part, to purely structural conditions in the areas of continuous deposition. Oil

occurs in basal Pliocene sands, in fractured shale of the Upper and Middle Miocene and in Middle Miocene sands. No production is known from formations older than Middle Miocene or from formations younger than Lower Pliocene.

The most prominent features of the present structural basin are due to earth movements active during Pleistocene time.

Santa Maria Valley

The Santa Maria Valley had been prospected for oil for about 30 years before the field was discovered. The final campaign of exploration which resulted in discovery was carried on by Union Oil Company in connection with a large block of land acquired initially by A. N. Macrate, who is original lessee of much of the present productive acreage. Through a study of regional geology and application of the information obtained from the drilling of a number of wells in the Valley, the Union began a search for the field which they believed should exist. After drilling four dry holes and one well which yielded minor production, Union completed the discovery well, Adam No. 1, at a depth of 2,472 ft. with an initial production of 2,376 bbl. per day of 16 gravity oil in April, 1936. The field was discovered entirely through abstract geological reasoning and interpretation of the information gained from a general geological survey and micropaleontological correlations.

Santa Maria Valley field is the largest field of any considered in this article. It is seven miles long, has a maximum width of one and three-quarter miles and comprises a total to date of 6,000 acres with three sides still remaining undelineated; 147 producing wells have been drilled and the field is approximately one-third developed. Potential production at the present time is about 125,000 bbl. per day but less than 15,000 bbl. per day is being currently produced. About 45 percent of the field is controlled by Union Oil Company. Other operators are A. N. Macrate, R. R. Bush, Hancock Oil Company, E. H. Moore, Inc., Geo. G. Getty, Inc., Pacific Western Oil Company, Signal Oil Company, California Lands, Inc., The Ohio Oil Company and several others.

Union Oil Company has 46 producing wells; Hancock-Bush, 18; Pacific Western, 14; and no others have more than 10. However, participation in the field is not proportional to the number of wells which reflects lease drilling requirements more than value.

Gravity of the oil averages about 15 deg. throughout most of the field but increases to about 18 deg. at the west end and is as low as 10 deg. in the southernmost well. Gasoline content is about 20 percent but is has been estimated that a yield slightly higher than 65 percent could be obtained by cracking. The oil is high (four percent) in sulphur and is a good asphalt stock.

Much has been written about overdevelopment in the Beacon area, locally called the hot spot, but actual drilling density is no greater than one well to four acres (10 wells on 40 acres in one instance), so the hot spot is not so hot as compared to some of the really densely drilled areas of Signal Hill and Santa Fe Springs. Dense drilling is about over, as the remainder of the field consists of larger leases held by companies whose programs follow a well to ten acre spacing.

Well depths vary between 2,000 and 5,300 ft. This shows a productive structural relief in excess of 3,000 ft. and wells whose production exceeds 2,000 bbl. per day have been discovered on both the deep and the shallow sides of the field. The Santa Maria Valley Field is probably unique in the world because of its 3,000 ft. structural range of production from the same formation.

The field produced 6,487,077 bbl. from discovery to Jan. 1st, 1939, and currently produces 10,000 to 12,000 bbl. per day, although the Umpire's allotment is 19,180 bbl. per day and its potential well over 100,000 bbl.

GEOLOGY*—The surface throughout most of the field is the flat floor of the Santa Maria Valley. Low undulating hills along the southerly margin of the field are due in part to deposits of windblown sand. Deposits of Recent, Pleistocene and Pliocene age extend to depths of about 2,000 to 5,000 ft. North of the field these formations are thinner, being only 634 ft. within a mile of production. The oldest Pliocene rocks are of the Sisquoc formation, which unconformably overlies both the Miocene and the basement rocks. Basal sands of the Sisquoc formation contain some oil and this zone is open to production in a few wells. Principal production is confined to a wedge of Miocene strata. The wedge point is the north limit of the field. North of the line of the wedge point, the Miocene rocks were completely eroded prior to Pliocene deposition, and, consequently, north of this wedge edge line the Sisquoc Pliocene formation rests upon the older basement rocks. Southerly from the wedge edge line, Miocene rocks lie between the base of the Sisquoc and the basement rocks. The Miocene rocks in the wedge dip south and the escape of oil has been prevented by the Sisquoc formation which was deposited across the truncated Miocene beds. Principal production occurs in a cherty zone in the Miocene Monterey shale. This cherty material, which is sometimes several hundred feet thick, is brittle, almost glassy in substance and by reason of its brittleness it has been fractured and granulated by various earth movements. This fracturing and granulation has resulted in a permeable porosity favorable in many places to prolific production up to 5,000-10,000 bbl. per day.

*Discussed fully by Charles Reiter Canfield in "Subsurface Stratigraphy of Santa Maria Valley Oil Field Bulletin Amer. Assn. of Petrol. Geol. January, 1939.

Productivity is extremely variable within the field and this variability is probably due to the degree of granulation and consequent induced porosity in localized areas. Initial productions of individual wells vary from less than 100 bbl. per day up to about 7,000 bbl. per day. As yet, no method has been devised by which the presence of areas of either scant production or prolific production can be determined other than by drilling.

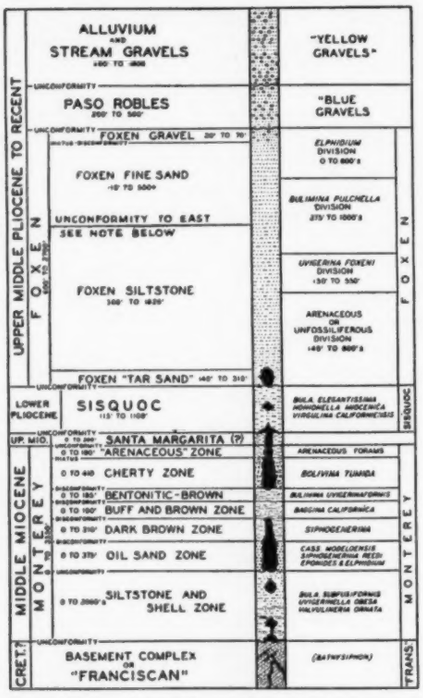
Gato Ridge

The Gato Ridge Field was discovered by Barnsdall Oil Company in Well Tognazzini No. 1, which was completed in 1931 at a depth of about 6,500 ft. It was later plugged back to about 2,500 ft. and produced oil spasmodically until 1936, when development of the field commenced. The field to-date consists of about 700 acres, in which production is obtained from wells at depths varying from about 2,300 to more than 4,000 ft. Total production from discovery until Jan. 1st, 1939, is approximately 2,324,713 bbl.

The field is an anticline in surface strata of Middle and perhaps Lower Pliocene age. A marked unconformity exists between the Pliocene, which extends to depths varying from 1,700 to 2,500 ft., and the underlying Miocene. The Pliocene formation is of soft silts and sands, which can be drilled at the rate of several hundred feet per day. By reason of the unconformity, the Pliocene overlaps upon the Miocene and a Pliocene oil sand is known to exist upon the fringe of the north end of the structure. This oil sand is in a buttress relationship to the Miocene and is absent from the top of the structure. This sand has produced negligible quantities of oil to-date.

Because of the unconformity, all wells do not encounter the same horizon in the Miocene below the Pliocene contract, consequently different amounts of penetration into the Miocene are necessary in order to secure production.

PRODUCTION ZONE—The main production zone is Middle Miocene, cherty or siliceous shale. No sand is present and the oil occurs in fractured or granulated areas of shale whose porosity is somewhat similar to that which might occur in broken or shattered glass. Production is contingent not only upon the structural position of the cherty shale zone but also upon



Standard stratigraphic section of Santa Maria Valley oilfield by Charles Reiter Canfield. From Bulletin of the A.A.P.G., January, 1939. Reproduced through courtesy of Mr. Canfield and the Association. The section is generally applicable in the district away from the Valley oilfield except that formation lithology and thickness change rather rapidly from place to place. To the east of the Valley oilfield a marked unconformity exists between the Foxen Fine Sand and the Foxen Siltstone. Because of this unconformity field geologists frequently limit the Foxen formation to Canfield's Foxen Siltstone, and map the Foxen Fine Sand as a separate formation for which the name Carreaga Formation has been informally used. The unconformity is great enough that in places the Foxen Fine Sand, or Carreaga, has overlapped as much as 2,000 ft. of underlying beds. An insert has been made by the writer.

the degree of its fracturing. For this reason, allocation of underground reserves are impossible. Initial productions vary from 100 bbl. per day to in excess of 4,000 bbl. per day. To-date, the field is known to have a productive structural relief of at least 2,000 ft. Production seems not confined to definite horizons within the cherty shale, but to come from those segments or, perhaps, kidneys within the cherty zone where fracturing has produced porosity. The field is too young to show any significant decline and the tendency has been noted in some wells for gas pressure and production to increase after several months.

OWNERSHIP—Most of the field is controlled by The Petrol Corporation and Barnsdall-Richfield. The field is poorly defined yet but might prove to extend in excess of 1,000 acres. Judging from apparent structural conditions, the final productive area may be well in excess of this figure but this excess outlying acreage is also held principally by Barnsdall-Richfield and The Petrol Corporation. Smaller amounts of acreage within the field are owned by O. C. Field Gasoline Corporation, The Texas Company, and Moyle Petroleum.

The Barnsdall-Richfield combination has six wells; the Petrol Corporation, five; O. C. Field Gasoline Corporation, two; and Moyle, one; total, 14 producing wells.

PRODUCTION — Although gas pressures have been on the whole low, large volumes of oil can be produced. Experiments conducted by the Engineering Department of The Petrol Corporation with six-inch pump and eight foot stroke have resulted in Gato Ridge's claim to the largest pumping oil wells in the world, one of which pumps in excess of 4,000 bbl. daily of 14 deg. oil.

An unusual feature in drilling is that as much as 1,900 ft. of hole has been drilled with rotary equipment without circulation. Clear water was pumped down but all the fluid, including the cuttings, was lost sidewise in the formation without returning to the surface.

Some of the west end oil from deeper wells is 10 deg. A.P.I. and is consequently more difficult to produce. A production hook-up devised by A. E. Ireland of O. C. Field Gasoline Corporation consists of two strings of tubing with injected distillate. Production from a 4,300 ft. well of 10 deg. oil was increased by the hook-up from 70 bbl. per day to 250 bbl. per day.

VENTURA

The first oil produced in Southern California was in the Newhall area in the eastern part of the Ventura Basin. Many discoveries have since been made, outstanding of which is Ventura Avenue Field. In the Ventura Basin occurs probably the greatest thickness of the Tertiary sediments in the world, the total thickness of the Eocene, Oligocene, Miocene and Pliocene rocks being somewhat over 40,000 ft. The total thickness of all sedimentary rocks from the base of the Cretaceous through the Pleistocene is about 60,000 ft.

In this basin, two important discoveries have been made since 1936. One of these, Newhall Potrero, discovered by Barnsdall Oil Company, is a major field occurring within a few miles of the old, original California oil development near Newhall. The Padre Canyon was discovered by Continental Oil Company and lies northwesterly from Ventura Avenue Field.

Padre Canyon

The Padre Canyon Field lies about six miles northwest of the City of Ventura and is situated about one and a half miles from the ocean. It was discovered by Continental Oil Company, March 22nd, 1936, when Hobson No. 1 well was completed for 570 bbl. daily, 31 deg. oil, cutting 7.7 percent and 200,000 cu. ft. of gas through a 40/64 in. bean from a total depth of 5,501 ft. Tubing pressure was 235 lb., casing pressure 600 lb. The producing zone was encountered from 5,092 to 5,501 ft.

All formations penetrated from the surface through the base of the oil zone are Upper Pico formation of Middle Pliocene age. The oil occurs in generally fine grained sand of good porosity but somewhat low permeability. The average zone penetrated is about 485 ft. thick, of which about 50 percent is oil sand. The oil zone is approximately 1,500 ft. higher stratigraphically than the Miley zone of Rincon Field on the coast to the west, and is about 4,500 ft. higher stratigraphically than the producing zone of San Miguelito Field to the southeast. Principal production is from the main, or Padre zone, but two deeper zones have been encountered in outpost wells and these zones should be productive throughout the field.

To-date, nine wells have been completed in the field and present production is approximately 100 bbl. per well with gas-oil ratio ranging from 750 to 1,100 cu. ft. per bbl. Three of the wells are operated by Continental Oil Company, five by Chanslor-Canfield Midway Oil Company and one by General Petroleum Corporation. Development has not yet been extensive and increased production may be expected from the two deeper zones already encountered in outpost wells and possibly from other deeper zones. The field produced 774,543 bbl. from discovery to January 1st, 1939.

GEOLOGY—It is geologically interesting that the oilfield occurs upon a downfaulted or graben block of the earth's crust. It has been faulted down along the Red Mountain thrust system at an angle of about 80 deg. (northerly) for some 10,000 to 15,000 ft. The southerly boundary of the block is the Madronio thrust fault system, the plane of which dips southerly about 75 deg. Its displacement is approximately 5,500 ft. The discovery of the field is due to carefully applied and interpreted geological study.

Newhall Potrero

The Newhall Potrero Field in the easterly part of Ventura Basin is in Los Angeles County, about six miles west of the town of Newhall. Wells are located in Sec. 26-4N-17 W. The field was discovered by Barnsdall Oil Company in March, 1937. The discovery well, Rancho San Francisco No. 1, was recompleted after deepening to 6,472 ft. on May 30th, 1937, with initial flow of 500 bbl. daily, 35 gravity clean oil. The well has been on production continuously and in January, 1939, still flows clean oil with a cut of 0.6 percent. The

second well was completed in February, 1938. This well established a 1,200 bbl. per day potential. Well No. 3 was completed in July, 1938, and was apparently a much larger well than either of the other two. It was drilled to total depth of 7,264 ft. and bottomed in oil sand. No flow potential was possible because of lack of storage but the well actually flowed 1,780 bbl. of 35.5 gravity clean oil, tubing pressure 1,020 lb., casing pressure 1,200 lb., 20/64 in. bean. Considering performance under these conditions, the per day production would undoubtedly have been several thousand barrels greater than the 1,780 bbl. per day flow. Under proration the well flows about 530 bbl. per day through a 12/64 in. bean, with tubing pressure 1,400 lb., casing pressure 2,150 lb.

Well No. 4 was drilled to 7,352 ft. and completed Dec. 17th, 1938, flowing at 1,100 bbl. per day rate through a 20/64 inch bean.

The field produced approximately 37,755-000 bbl. of oil from discovery to January 1st, 1938. Production during 1938 was 242,441 bbl. The field is currently producing about 720 bbl. daily of 33 deg. A.P.I. average oil, which is moved out of the field through a pipeline to Union Oil Company, and 280,196 bbls. were produced from discovery to January 1st, 1939.

The producing zone as known in well No. 3, which has the greatest penetration, is at least 1,000 ft. thick. At least half or more than 500 ft. is composed of oil sand, which becomes coarser and more permeable toward the bottom. Bottom hole pressures recently made indicate 2,800 lb. The gas-oil ratio is about 700 cu. ft. per bbl. Gas production is about 1,000,000 cu. ft. per day with gasoline content of 1.7 gal. per 1,000 cu. ft. Barnsdall Oil Company expects to build its own plant for treatment of gas. Octane rating of the straight run gasoline is about 69.

It seems probable that in the neighborhood of 1,000 acres will be productive. The field was discovered by detailed geological mapping supplemented by seismograph work, which indicated sub-surface geological conditions upon which the discovery location was made. All the exploration work was done under the direction of R. W. Sherman, consulting geologist, formerly Chief Geologist for Barnsdall Oil Company, and E. Wayne Galliher, formerly Assistant Chief Geologist but Chief Geologist since Mr. Sherman's resignation.

GEOLOGY—The geosynclinal axis of the Ventura Basin trends east-west and lies north of the field. To the south of the field in the Santa Susana Mountains is the prominent Pico anticline. The Newhall Potrero oilfield is situated upon a northwesterly plunging rib of the Pico anticline. An east-west fault on the south side of the field has trapped the oil and prevented its migration up the plunge toward the top of the Pico anticline. The plunging anticlinal rib, or nose, is apparent at the surface where the outward dipping escarpment rocks bow around the meadow, or *potrero*, in which the field is located. Flank dips are approximately 25 to 35 deg.

Strata from the surface to about 2,000 ft. are composed of Upper Pliocene Pico shale, which comprise hard grey, uniform shale bodies. The position of the basal contact of the Pico with the Repetto is not certainly known. Below the Pico is encountered about 4,000 ft. of Lower Pliocene Repetto formation, which consists of sandy dark grey shale and sands. Top of the Upper Miocene is encountered at about 6,000 ft. and has been penetrated to-date only to depth of about 1,250 ft. The Miocene shale is of platey, organic type and is interbedded with various silty and impermeable sands and with permeable oil sands.

PRODUCING ZONE—The producing zone is the permeable sand member of the Upper Miocene Modelo formation. In well No. 3, the interval from the 8⅝ in. casing shoe at 6,242 ft. to bottom at 7,264 ft. was composed of about 50 percent oil sand, the permeability of which increases with depth. Neither a free gas cap above nor bottom water have been encountered, although a minor amount of connate water was noted in some cores.

DEVELOPMENT—The field is being developed in a slow and orderly manner, with a program of 10 acres per well as the ultimate objective. Two thousand feet of casing is set at the base of the Pico and 8⅝ in. casing at the top of the oil sand, with 5¾ in. perforated liner hung through the producing zone; 2⅓ in. tubing is used and extends into the liner.

OWNERSHIP—The Newhall Potrero field is unusual in that the entire structure and considerable surrounding country is owned by one land owner, Newhall Land and Farming Company, and the entire 4,000

acres is controlled by one operator, Barnsdall Oil Company, with lease terms uniform throughout the field. Because of this, the field has not in general received interest commensurate with its importance.

Aliso Canyon

Discovery of a new field in the mountains north of San Fernando Valley, Los Angeles County, resulted from exploration by Tidewater Associated Oil Company. The discovery well, Porter No. 1 was completed October 25th, 1938. Initial production was about 650 bbl. per day, but the well rapidly cleaned and flowed 1,320 bbl. per day of 23.8 deg. A.P.I. oil cutting less than 1.0 percent. Total field (one well) production to January 1st, 1939, was 23,416 bbl.

The geology is complicated and as yet imperfectly known. Drilling commenced in the *Valvulinaria colifornica* zone of the Middle Miocene, and passed out of Miocene sediments at the Santa Susana fault plane at 1,895 ft. Below the fault plane which dips northerly at a low angle the Saugus formation of Pleistocene age was encountered. At about 2,400 ft. the well was in Pico, and was bottomed in Middle Pico, Upper Pliocene at 5,391 ft. The oil is produced from sands in the Middle Pico formation. Oil showings were encountered from about 2,900 ft. to bottom, but several tests of upper showings proved unsatisfactory, and present production is from below the 6⅝-in. casing shoe at 4,795 ft. and above the plug at 5,365 ft.

Until much more information is available concerning conditions beneath the Santa Susana fault plane it is impossible to discuss the buried geological conditions, whatever they are, that control the oil accumulation. It seems apparent, however, that an important discovery has been made.

The well is located 2,442 ft. south and 3,010 ft. west from the northeast corner of section 27, Township 3 north, Range 16 west. Elevation 2,180 ft. Adjacent land is held by Standard and Union, but as only one well is on production yet, the value of these holdings is unknown. Both Standard and Union are drilling.

LOS ANGELES

The Los Angeles Basin in a structural classification is the area lying east of the Pacific Ocean and west of the mountain arc which extends from near Santa Monica where the Santa Monica Mountains meet the ocean, in an arc around the Basin, and to the sea again in the neighborhood of San Juan Capistrano.

Many major oilfields, such as Santa Fe Springs, Huntington Beach, Signal Hill and others, have been discovered in this basin. It is of interest that in spite of the density of population and geological scrutiny to which this relative small area has been subjected during the last 40 years, major oilfields continue to be discovered.

Within the period treated in this article, two important fields have been developed in Los Angeles Basin. One of these, Wilmington, is of top rank major importance and the other, El Segundo, might be classed as a major field. Strictly speaking, El Segundo was discovered prior to the period here discussed by a well completed by Republic Petroleum Company in August, 1935. This was the only well in the field until April, 1936, and only four wells had been completed by December, 1936, consequently a brief discussion of the El Segundo Field will be included in this article. Too much has already been written on the Los Angeles Basin to warrant further discussion. It is perhaps ironical that portions of both of these fields were found to exist beneath long held refinery sites of some of the major companies.

El Segundo

On August 24th, 1935, Republic Petroleum Company completed El Segundo No. 1 at a depth of 7,204 ft. flowing 400 bbl. daily, 28 gravity oil. To the end of 1935, this well produced 19,555 bbl. or a daily average of about 160 bbl. Two more wells were subsequently drilled but the existence of an important field was not evidenced until completion in December, 1936, of a well by Richfield Oil Corporation which produced 2,533 bbl. of 27.2 gravity oil. In May of the following year, The Texas Company completed Security No. 1 in the westerly portion of the field for 4,563 bbl. daily. Considerable development subsequently took place, with the result that the field had produced 7,651,147 bbl. of oil from discovery until Jan. 1st, 1939. Production of El Segundo Field is currently between 3,000 and 4,000 bbl. per day.

GEOLOGY—Recent and Pleistocene beds are encountered near the surface, after which the Pliocene extends to a well depth of about 5,200 to 5,500 ft. The Miocene consists of 2,000 ft. to 2,300 ft. of sand, siltstone and shale, the lowermost portion of which is the conglomeratic production zone which varies in thickness from zero up to 100 ft. Directly above the production zone is the Nodular shale. This is a brownish to dark-grey shale containing a number of phospatic nodules which appear as light tan to grey kidneys or eyes up to two inches in diameter. Nodular shale is approximately 200 ft. thick. In the eastern portion of the field, the Nodular shale overlies coarse greenish to grey conglomerate, containing both quartz and schist pebbles up to two inches in diameter. In the conglomerate and associated sections, porosity varies from 16 to 28 percent. Some good production, such as that of Richfield Oil Corporation, El Segundo No. 1 (initial production 2,533 bbl. per day) has been obtained from this basal conglomerate but many wells have been disappointing, being capable of producing only 100 to 150 bbl. Gas-oil ratios in this eastern area average about 650 cu. ft. per barrel.

The above discussed eastern portion of the field is separated from the westerly portion by a northwest trending zone of faulting, west of which the nodular shale rests directly upon the basement schist, the conglomerate being absent. Various chemical and structural factors have induced an erratic porosity in the schist itself. This porosity is variable both above and below about 15 percent and wells fortunate enough to have encountered particularly porous areas in the schist have had yields of up to 4,000 bbl. per day. Apparently the structural relief in the field is about 500 ft. Production from the schist is due merely to the existence of porous reservoir material near a source of Miocene oil and has no significance or bearing on the productive possibilities of basement rocks. The erratic localization of schist porosity and variability of the oil-bearing conglomerate thickness which are indeterminate by any method but drilling make reserve estimates extremely difficult and preclude entirely any possibility of compulsory proration or drilling control based on acreage allotments. L. E. Porter, petroleum engineer for the Richfield Oil Corporation, has stated that "each well must be considered as a semi-wildcat. There are examples of wells producing several thousand barrels per day being offset by wells producing less than 100 bbl. per day."*

Because of the variable productivity within the field, any reserve estimate can have no better standing than a mere guess and perhaps not a good guess, either. To bring out the general category of the field, the writer timidly suggests 20,000,000 bbl.

OWNERSHIP—The Caminol Company, Ltd., Geo. F. Getty, Inc., The Ohio Oil Company, Pacific Western Oil Company, Republic Petroleum Company, Richfield Oil Corporation, Royalty Service Corporation, Standard Oil Company, The Texas Company, and Union Oil Company are the principal lease holders in the field.

Ohio has 11 wells, Richfield six, Standard Republic and Texas five each, and others less than five.

GENERAL—Casing programs ordinarily involve a 13⅜ or 11¾ in. string at 700 to 1,100 ft. with 8⅝ in. or seven inch respectively cemented on top of the oil zone and perforated liners to bottom. Sulphur content of the oil is about 1½ percent and gasoline yield about 28 percent from the 27 to 28 deg. crude. Irregularity of productivity

*L. E. Porter, "El Segundo Oil Field," Transactions Amer. Inst. of Mining and Metallurgical Engineers, Petroleum Division, (Petroleum Development and Technology in 1938).

Photo by E. Wayne Galliher — Spence Air Photos, Los Angeles

View looking northwest at Barnsdall Oil Company's Newhall Potrero field. Prominent strata at the right are Saugus formation of upper Pliocene or early Pleistocene age. At the extreme left, marked X, is the axis of the Pico anticline. Beds outcropping at the surface at X are of upper Miocene age and are the same zone from which production is obtained in the Newhall Potrero field from wells near the center of the picture, at depths of about 6,500 ft. Shallow wells in the old Pico field spud into the surface outcrop of the sand which the Barnsdall wells encounter at depth. The picture also illustrates the amount of structural movement that has taken place since Pliocene time. Inset is a picture of the area indicated at X in the air photo. The old derricks at the left are on the surface outcrop of the Newhall Potrero production zone.

prevents any acreage outside the drainage radius of individual wells from being considered proved. The over-all of the limits of the field may include some 1,500 acres.

Wilmington

Although sporadic indications have been known in the Wilmington area for several years, discovery of the field proper dates from December 6th, 1936, when General Petroleum Corporation completed its well, Terminal No. 1, for initial production of 1,500 bbl. daily of 20 deg. A.P.I. oil from the upper 600 ft. of the Miocene, discovering what is now known as the Upper Terminal zone. Several hundred wells have since been drilled and the discovery of more than four distinct productive sands has led the field to occupy the position of one of the major fields of the state.* There were 588 producing wells in January, 1939.

*E. J. Bartosh, Geologist of the Bankline Oil Company, in Bulletin of American Association of Petroleum Geologists, August, 1938, has described the Wilmington Field in a comprehensive manner. The writer is indebted to Mr. Bartosh for much supplementary information.

The Wilmington Field is unique and outstanding in several respects. It is perhaps the only major oilfield occurring beneath both refinery and marine terminal sites and is probably one of the few fields in which valuable acreage was acquired by the transportation and refinery departments of several major oil companies. The field occurs beneath the industrial and harbor districts of Los Angeles and Long Beach. Much of the surface of the field is occupied by factories, city buildings, warehouses, deep sea dock facilities, power plants, bathing beaches, railroad yards, highways, streets, refineries, yacht clubs and residences. If desirable, it would be possible to flow wells into deep-sea tankers instead of lease storage tanks.

GEOLOGY—There are, strictly speaking, five oil zones in the Wilmington Field but the upper or Tar zone is of relatively minor importance and will not be discussed. The important zones are the Ranger zone of basal Pliocene age, and the Upper Terminal, Lower Terminal and Ford zones in the Upper Miocene.

Pleistocene and Recent deposits extend to depths near 700 ft., below which they are underlain by the Upper Pico formation of Upper Pliocene age. These Upper beds are approximately 1,000 ft. thick. Below the Upper Pico is an unconformity which accounts for the entire absence of the Lower Pico and the absence throughout much of the field of the Middle Pico. The Pico is underlain by about 1,000 ft. of the Lower Pliocene Repetto formation, in which occur the Tar zone and the Ranger zone.

The Tar zone is 100 to 300 ft. thick, of which approximately one-third is oil sand containing 12 to 15 deg. oil. A few wells have produced as much as 300 bbl. daily from this zone.

The Ranger zone consists of 200 to 350 ft. of dense, massive clay shales and siltstones interbedded with oil sands which occupy 25 to 35 percent of the total zone thickness. The top of the Ranger zone is

encountered at well depth of about 2,400 to 3,500 ft., according to the position on structure. The Ranger zone oil varies from 14.5 deg. to slightly over 23 deg. A.P.I., and initial productions range from 50 bbl. daily to 3,000 bbl. daily, with the average preponderantly toward the lower figure. The wide range in gasoline content is from 3 to 21 percent and the sulphur content is high varying up to 2.2 percent. Sand troubles are rather common but have been handled successfully by the installation of Torrance heaters.

The base of the Ranger zone is the base of the Repetto formation and the base of the Pliocene. About 3,200 acres are productive from the Ranger zone from well depths of 2,500 to 3,500 ft., the structural relief of productivity being approximately 1,000 ft.

The uppermost 200 ft. of the Miocene in Upper Terminal Zone consists of brown clay shales and diatomaceous shales which separate the basal Pliocene Ranger zone from the Upper Terminal zone. The Upper Terminal zone is approximately 500 ft. thick, of which approximately 65 percent is oil sand, yet the effective productive thickness of oil sand decreases to 40 ft. near the edge of the productive area and to zero in nearly half of the field, the Upper Terminal productive area being about 1,700 acres in contrast to the 3,200 acres of Ranger production. The Upper Terminal initial production ranges up to 4,000 bbl. daily, of 17 to 25 deg. A.P.I. oil. which has a sulphur content up to 2.5 percent. The gravity of the oil is definitely related to faulting, the lower gravity oil with the highest suphur content being produced from the area west of the Wilmington fault. Sand porosity is about 25 percent.

The Lower Terminal Zone is approximately 600 ft. thick, of which about 50 percent is sand saturated with oil on top of the structure. The zone, as a whole is harder and more finely cemented than the Upper Terminal but initial productions are similar, ranging up to 4,000 bbl. daily of 27 to 33 deg. A.P.I. oil.

The large capacity wells occur where the two Terminal zones are each fully saturated with oil at the top of the structure. In this area in the eastern part of the field where the two Terminal zones have a total thickness of 1,100 ft., of which approximately 600 ft. is oil sand, occur the larger wells with initial productions up to 10,000 bbl. per day. The Lower Terminal Zone is productive throughout about 1,000 acres.

The Ford zone was discovered by General Petroleum Corporation under the Ford Motor Company lease in wells bottomed at about 5,700 ft. It consists of an upper zone about 600 ft. thick and a lower zone about 250 ft. thick. The zone is known in a relatively small area of uncertain extent. Of the total thickness, only about 25 percent is oil-saturated at favorable points on the structure. Initial productions have been obtained up to 700 bbl. daily in the upper part and up to 400 bbl. daily in lower part of the zone. Oil is about 27 to 32 deg., and the producing sand is fairly well cemented and gives little trouble.

Both Terminal zones and the Ford zone occur in the Upper Miocene generally known as the Puente formation. Deep tests encountered a thin section of Middle Miocene formation from 6,425 to 6,787 ft., at which point the basement rocks of Franciscan schist were encountered. The *Valvulinaria californica* zone was identified from micro fossils which were particularly abundant from 6,673 to 6,680 ft.

STRUCTURE—The field is essentially a broad, anticlinal dome at least four miles long and about two miles wide with a maximum productive closure of about 1,200 ft. on the Ranger zone and about half that amount on the Terminal zones. The highest part of the structure centers near the east end of Terminal Island. At least five important cross faults are known. These faults exert a marked influence upon both the gravity of the oil and upon productivity. The movement on most of the faults is down on up-structure side and this has produced a series of stepped traps in which high productivity occurs where migration up the plunge has been interrupted by the faults. The amount of displacement ranges from approximately 25 to 50 ft. on minor faults to approximately 275 ft. on the Wilmington fault. A recurrent movement is evident where displacement in the Miocene is sometimes more than twice the amount of the displacement in the overlying Pliocene.

Particularly curious is the effect of the Long Beach Harbor fault, which runs in a roughly north-south direction through a point approximately 1,200 to 1,500 ft. east of the eastern-most point of Terminal Island. Although Miocene strata at the Miocene-Pliocene contact have been displaced downward on the east only about 100 ft., nevertheless the Upper and Lower Terminal zones and the Ford zone are barren of oil east of the fault, except where they are locally productive due to other faulting.

PRODUCTION—From discovery to Jan. 1st, 1938, the field produced 14,262,377 bbl. of oil and 34,167,860 bbl. during 1938, making a field total of 48,430,237 bbl. to Jan. 1st, 1939. Production was about 82,000 bbl. per day in January, 1939,

Approximately one-third of the field is owned by the Union Pacific Railroad who has drilled 118 producing wells. General Petroleum Corporation has 93 wells, Sunray 51, Bankline 40, Richfield 36, Hancock 14, Royalty Service 14, Superior 14, Pacific Western 13. The remaining wells have various ownerships.

GEOLOGY

Every one of the fields was discovered as a result of carefully planned and coordinated geological exploration aided in most cases by reflection seismograph surveys. None of the fields was discovered by a random well. Studies involving both the details of surface geology and consideration of general regional geology formed the basis upon which it was decided where seismograph work would be advisable. Seismograph work is amazingly accurate as discovery of several prolific fields has proven.

The discovery of oil and gas-bearing structures beneath the flat floor of San Joaquin Valley in the central portion away from the marginal folds has important geological significance. The information gained from this exploration and development has yielded an insight into subsurface structural and stratigraphic conditions, and this insight has every probability of leading to the discovery of important oil and gas fields in the future.

The discovery of gas in the few relatively shallow Cretaceous tests in northern San Joaquin Valley carries the implication that the 30,000 foot Cretaceous section of northern California must be seriously considered as a source of future reserves. These rocks have been seriously considered for several years by the few companies who have pioneered northern California development. Gas discoveries made to-date substantiate the wisdom of that far-sightedness.

Regional geology of California has long indicated that compared with other sections of the United States, fairly steep and close folding is the rule. In the light of this knowledge, it will be rather amazing if the few folded structures thus far discovered on the San Joaquin Valley floor should prove to be the only such folded structures.

Discovery of well-saturated oil reservoirs deep in the central part of the Valley also adds significance to the possibility of additional stratigraphic types of accumulation around the valley rim, such as the prolific Eocene field at East Coalinga.

Although more oilfields may be discovered in the Santa Maria embayment, and the Ventura and Los Angeles basins, developments in these latter areas are more significant as indicating the efficacy of scavenger geology than they are as indicating the vastness of probable future reserves. When new fields are discovered in Los Angeles Basin, their discovery reflects the efficiency of interpretative geology rather than a significance of future-to-be-discovered reserves. This principle applies to the discovery of new fields and not to deeper prospecting in the existing fields.

The obtaining of cores from depths of two to three miles in some of the newer fields in California does not have a significance commensurate with the publicity in popular publications. Geologists have long been familiar with the character of rocks buried 15,000 ft. and even 40,000-50,000 ft. below the surface, because in many places structural movements have folded or faulted these various once-buried rocks to the surface where they may now be studied. Furthermore, rocks have actually been studied to depths of more than a mile and a quarter in underground working in mines, such as the 8,530 ft. shaft of the Crown Mines on the Rand in South Africa.

There has been ample evidence for many years that structural deformation has taken place at depths far exceeding that of the deepest oil well. Considering the known thickness of sedimentary rocks in California which in several places exceeds 30,000 ft., there is no reason why structurally trapped reservoirs should not exist many hundreds of feet deeper than the greatest depth thus far explored. The oil from depths below 13,000 ft. shows no important effects of depth and considering the not severe thermal gradient (270 deg. at 15,000 ft. in Continental Oil Company's K.C.L. A-2) of the earth and the general effects of critical pressure upon liquid and gaseous phases, the writer believes that oil may be found at depths considerably greater than those thus far penetrated by the drill, If suitable structural traps and drainage areas exist at great depths, such reservoirs will probably contain oil if oil sources are in the sediments. Contrary opinions have been expressed from time to time.

The combined effects of geology and engineering in a newly growing branch of science which might be called geological engineering is illustrated by Standard Oil Company's discovery of Los Flores field. Although the well was located on the surface axis of an anticline, steep dips were encountered at about 5,000 ft. This indicated that the subsurface structure was asymmetrical and that the well was down on the steep flank. Magnetic orientations of the cores were determined and the geological department was able to tell in what direction and at what angle the well should be redrilled to encounter the crest of the anticline. The well was whipstocked and redrilled to the point where the crest of the anticline had been calculated to be. The calculations proved to be correct and the redrilled hole resulted in the discovery of a new oilfield.

The relation of the occurrence of commercial oilfields to the peculiarities and details of sedimentation has been brought forcefully into prominence by the sharply defined limit of the Gatchell oil sand at East Coalinga, and the absence of the Greeley oil sands at Rio Bravo. The importance of stratigraphic studies has thus been brought pointedly to the attention of the oil industry as a whole.

The most far reaching practical effect of the group of discoveries has been the increment to geological knowledge of the San Joaquin Valley floor. The discovery of prolific oil pools in the Miocene and Eocene rocks of the Valley and the discovery of commercial gas in Eocene and Cretaceous rocks in the northern San Joaquin Valley are all elements that presage future discoveries of major oilfields in the San Joaquin Valley.

ENGINEERING

New discoveries have contained certain elements which would have provided serious problems had they not been solved by the ingenuity of petroleum engineers.

Wilmington Field offers several examples, one of which was to reduce the number of necessary wells at a saving of millions of dollars. This was accomplished by perfecting cementing and production technique to such an extent that it is possible to produce three separate and distinct oil horizons independently and without contamination from the same well. This is accomplished by several accurately spaced and successfully completed cement jobs. Production is obtained from the Lower Terminal zone, Upper Terminal zone and Ranger zone, through tubing and two annular spaces and is dispersed at the surface through three sets of flow lines from a compound Christmas tree.

Dexterity and refinements in methods of directional drilling have resulted from the necessity of completing wells at their proper location on the spacing grid where no surface location was available. The field is in the industrial harbor district, where much of the surface is occupied by docks, factories, the Ford motor plant, warehouses, waterways of the harbor and other industrial sites. Many wells have of necessity been commenced wherever space was available and have been bottomed by directional drilling at their proper position on the spacing grid, perhaps under a soap factory or perhaps under a power house. The cost of directional drilling has been materially reduced.

Infiltration of sand into wells in the Ranger zone has, in many instances, been greatly reduced by gravel packing and by mechanical analysis of the size of sand grains. Sand troubles have been greatly reduced by choosing liner perforation slot width from results of mechanical sand analysis, the slot size being barely smaller than the preponderant sand grain diameter. Dehydration and de-sanding of some of the Ranger zone oil has been accomplished by the use of a Torrance heater. The heater works on a principle somewhat similar to the ordinary dwelling house hot water heater. Regulation and control of the desired temperatures is accomplished by a thermostat. Continuous circulation of hot water through coils of the sand trap and shipping tanks serves to heat the oil to a temperature at which sand and water drop out. The same circulation system also serves to maintain oil in the storage tanks at a temperature desirable for shipping. This process is important because of its cheapness. Torrance heaters are also used for heating and shipping the heavy oil in the Gato Ridge and Santa Maria Valley fields.

The outstanding liner of 1938 was designed and set by Continental Oil Company in the world's deepest well at Wasco. The liner containing a bull plug shoe, concrete baffle, special cement whirler collar, 900 ft. of right-handed aluminum tubing, packing rubber, sleeve with lock pack-off, swab rubbers, upper cementing barrel with basket, liner hanger, releasing tool and other minor accessories, was made up at the surface and lowered into the hole as one unit with the drill pipe. All fittings within the liner were composed of drillable material, principally aluminum. Two cement jobs were then successfully completed, and the well put on production.

Streamlined Christmas trees are a recent development whose advantages eliminating right angles in the flow system are obvious, while the science of metallurgy has made a most important contribution by providing the proper types of steel for the heavy equipment used.

Use has been made of many other technical improvements in the development of these new fields. Some of these are: 15,000 ft. Schlumberger cables; 178 ft. derricks, such as used by Superior Oil Company in drilling more than 10,000 ft. in 24 days at Rio Bravo; magnetic orientation of cores; 14 by 14 in. steam drawworks engines; separate drive for rotary table with speed of more than 400 r. p. m.; steel base derricks which are readily skidded; long drill collars totaling sometimes up to 360 ft. to provide a stiff assembly for fast straight drilling; unitized 350 lb. boilers, which can be moved and set up at a new location in 24 hrs.; colloid and weight material (usually bentonite and barite) to produce heavy but fluid drilling mud that will not cake excessively; and drillable aluminum liners that permit testing but do not preclude carrying the hole deeper without reduction if the test is a failure.

RESERVES

A table of the reserves discovered is given with full knowledge of the errors that must inevitably be involved and of the revisions that must be made from time to time as

development progresses. Many reserve estimates involve financial considerations. In estimates of that type, the policy is usually to recognize the possibility of error and to take no chances upon the error being expensive—in other words to use buyers' figures. For the purposes of this article, it is quite immaterial to the writer whether the estimate be too large or too small and whatever the percentage of error, it may as well be on the high side as on the low side, but the figures here given should not be considered as maximum figures. The writer takes full responsibility for the estimates, as in several cases they are at variance with the opinions held by the owners of the reserves.

Weight has been given to some general factors not included in the data ordinarily used in volumetric estimates. One of these has been the general tendency for most past estimates to be under-estimates. Another has been the writer's inclination to discount the modesty and reluctance of some operators to admit their ability to achieve above average recovery percentages. The figures given, therefore, represent an unbiased guess at what the total recovery may be without regard to whether the inevitable error will cause the figures to be high or low.

The reserve figures in the table refer to barrels of oil discovered, not to barrels of oil developed. Such figures necessitate consideration of the geological factor and must take into account the probable or, at any rate, possible extent of fields in which the acreage actually proved by drilling is relatively small.

Some figures have been given when it is obvious from the incipient state of development that an accurate figure embodying the orthodox methods of investigation would be impossible. It might seem preferable to desist from naming figures in such cases and to state simply that the reserve is unknown. The writer has failed to do this, because he is of the opinion that the error introduced by ignoring the potentialities of known discoveries would be a greater error than that introduced by the figures given. It would be simpler to say concerning Los Flores, for example, that only one well has been drilled and the reserves are unknown. Yet when there is evidence that the geological structure is larger than the few acres surrounding the well, and when there is evidence that production approximating 30,000 bbl. per acre has been produced from similar reservoirs, greater accuracy will probably prevail by use of the 30,000,000 bbl. figure than would prevail by ignoring the situation, notwithstanding the paucity of facts available through actual development. Similar reasoning accounts for the reserve figures of several other fields. Such figures can be weighted by considering acreage, number of wells, and reserve.

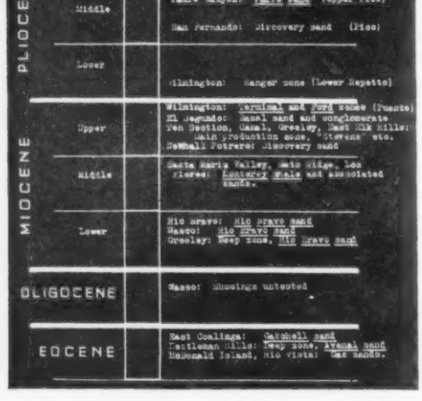
The total group reserve figure is probably more accurate than any particular individual figure, because some errors have probably been leveled by compensation. Best figure is probably the round number one for the group. That is, that the exploration efforts resulted in discovery of approximately 1,500,000,000 bbl. of oil.

General Data on Recent California Oil Discoveries

Field	Discoverer	Discovery date	Daily Potential Jan. 1 1939	Quota Jan., 1939 B/D	Approx. daily prod. Jan. 1-6 1939	Acres (Geol. structure)	No. of wells Jan., 1939	Original Reserve (millions of bbl.)	Total prod. to Jan. 1, 1939
SAN JOAQUIN VALLEY:									
Coles Levee	Ohio	Nov. 1938	875	177	170	1,000	1	30	10,345
Canal	Ohio	Nov. 1937	25,750	3,910	3,935	800	15	50	880,729
East Coalinga (Eocene)	Pet. Sec.—Seaboard—Hololulu	June 1938	48,750	2,500	3,356	1,000	9	70	245,780
Greeley	Standard	Dec. 1936	15,485	2,540	1,856	1,500	19	160	1,695,477
Richfield Western	Richfield	Nov. 1938	3,000	280	300	1,000	1	50	1,668
Rio Bravo	Union	Nov. 1937	132,880	6,570	8,090	2,000	24	200	2,072,412
Ten Section	Shell	June 1936	59,800	8,770	8,524	1,800	34	135	3,593,670
Wasco	Continental	Apr. 1938	9,175	635	522	1,000	2	40	125,063
SANTA MARIA DISTRICT:									
Santa Maria Valley	Union	Apr. 1936	112,360	19,180	10,794	6,000	137	180	6,487,077
Gato Ridge	Barnsdall-Richfield	1931*	16,250	2,215	3,521	700+	14	15	2,324,713
Los Flores	Standard	Aug. 1938	850	148	.....	1,000	1	30	18,461
VENTURE BASIN:									
Padre Canyon	Continental	Mar. 1936	1,300	635	728	500	9	15	774,543
Newhall Potrero	Barnsdall	Mar. 1937	5,475	790	700	1,000	4	75	280,196
Aliso Canyon	Tidewater-Assoc.	Oct. 1938	1,340	203	250	1,000	1	25	23,416
LOS ANGELES BASIN:									
El Segundo	Republic	Aug. 1935	5,905	3,680	4,120	1,600	52	17	7,651,147
Wilmington	Gen. Pet.	Dec. 1936	469,243	69,260	82,675	3,300	588	400	48,430,937
TOTALS			901,438	121,493	129,541	25,200	911	1,492	74,614,934

*Gato Ridge discovered in 1931, but not operated or developed until 1936. NOTE: Read text for discussion of reserve figures.

Geological age of important productive horizons discovered in California from 1936 to 1938.



ECONOMICS

In the discovery wave which followed 1935, approximately 1,500,000,000 bbl. of new oil reserve have been discovered in California. No major additions to reserves had been made since Kettleman Hills, Elwood, and several other fields were discovered in 1928; and additions since 1931 had been little more than nominal. Because of small additions to reserves from 1928 to 1935, each year's production decreased the state potential. It was estimated that without new discoveries, the potential curve would cross the demand curve in 1941, creating a shortage*.

Wildcatting activity was rather desultory from 1932 to 1935, but rose rapidly between 1935 and 1938.

Wildcat Drilling Activity†

	1932	1933	1934	1935	1936	1937	1938
San Joaquin Valley and Northern California	37	22	41	72	93	148	...
Costal Area	25	16	27	24	81	48	...
Los Angeles Basin and Southern California	22	22	21	24	35	36	...
TOTAL	84	60	89	120	209	232	

As the result of this wildcatting activity, which commenced in the latter part of 1935, more than a dozen important oilfields were discovered and a reserve of well over 1,000,000,000 bbl. of oil has been indicated. It will be produced from a total of slightly more than 25,000 acres. This group of fields has produced so far more than 74,000,000 bbl. and currently produces about 130,000 bbl. per day. In the event of national necessity, these fields could with little effort develop 1,000,000 bbl. per day. A huge national asset has therefor become available.

Actual effect of this reserve upon local markets and upon future exploration will apparently be nominal. The reason for the apparent paradox of a huge available reserve having a disproportionately minor effect on the market is that more than 80 percent of the total reserve discovered is owned, or controlled by contract, by about six major marketing companies. It is probable that an even greater proportion is similarly controlled through crude oil purchase contracts not generally known. At least four-fifths of the reserve may therefor be considered ear-marked for disposition by some half dozen companies. These companies are refiners and marketers of gasoline and will undoubtedly maintain their reserves for their own use rather than make the oil available in the general crude oil market. This same group of companies collectively market slightly less than one-half

†These figures are not accurate, and are dependable only as indicating approximate trends.

*J. E. Eaton, "California Oil Reserves," The Oil Weekly, July 1st, and July 8th, 1935.

of the total gasoline sold in California. Therefore, only the relatively nominal amount of some 250,000,000 bbl. of crude oil from this reserve will find its way into the general crude oil market. The large number of companies, which as a group sell the other half of the state's gasoline, are in the same position with respect to 80 percent of the new reserve that they would have been in had it never been discovered. The reserve consists essentially of two parts—the 80 percent ear-marked reserve and the 20 percent available reserve. The crude oil market is affected only by the available reserve. The ear-marked reserve has little general effect except upon the companies who own it. California needs to discover approximately 250,000,000 bbl. of oil per year to maintain its productive potential. The available reserve of some 250,000,000 bbl. from these new fields about equals the quantity annually necessary to maintain potential production. On this analysis, it appears that the marketers of more than half of the state's total gasoline are as badly in need of new oil reserves as ever, and will be active as buyers of crude oil and in the search for new oilfields. It is unlikely that the crude oil market will be greatly affected by the existence of the ear-marked reserve because its owners have a large stake in the gasoline market. Gasoline profits are contingent upon a stabilized price of crude oil and would be greatly reduced by the general availability of a large quantity of cheap crude oil.

It is quite likely that the existence of the ear-marked reserve will have a stabilizing rather than a weakening effect upon the market. A high percentage of the oil from reserve can be obtained by flowing wells, and the production cost per barrel must necessarily be comparatively low during the flowing lives of many of the fields. Possession of this reserve implies not merely possession of 1,000,000,000 bbl. of oil but also possession of a large quantity of cheaply available oil. If competition exists between refiners depending upon pumped oil for their supply and other refiners whose crude supply comes from flowing wells, this competition which in large part must depend upon the price of available crude would obviously have a reaction favorable to the owners of the flowing wells. As this situation is well known, it may have a deterring influence toward preventing cutthroat price wars.

PRORATION

The demand for California petroleum products varies in the neighborhood of 600,000 to 650,000 bbl. per day, although the total over-all demand for the year 1937 was 709,800 bbl. per day. The figure is abnormal in that it includes approximately 82,000 bbl. per day purchased by Japan. The Japanese needs, accentuated by the war in the Orient, will probably be transitory rather than a permanent element in the California market. Production of a magnitude roughly expressed by the above figures is under present circumstances the maximum that can be marketed.

The California oil industry attempts by voluntary methods, without legal coercion, to maintain production consistent with the above demand. The net final effect of voluntary proration was to maintain a reasonable price of crude and to keep the average daily production for 1937 at 653,444 bbl. Whatever may be said as to the details of proration, it must be conceded that a system that can accomplish the above result is a workable system and it seems to be preferred by most Californians to any system involving legal or political interference. All of the new fields are at the present time successfully prorated.

In a few isolated instances, the Division of Oil and Gas of the State of California has intervened in behalf of conservation to prevent the excess production and blowing to air of gas. The occurrence and extent of such occasions are so minor as to be practically negligible. A great deal has been written upon the subject of waste but most of these writings which have appeared in popular magazines and elsewhere are utterly inapplicable to California. All of the fields discussed in this article are being produced in a scientific manner utilizing the best available technical skill to bring about maximum recovery of oil, and a maximum utilization of reservoir energy. In other words, present methods of oilfield operation under existing laws are definitely in the interest of conservation and efficient utilization of natural resources.

It does not follow that all is calm and serene under the present proration system, but it is a fact that the main objective was accomplished in 1937, and that it has been accomplished in 1938. The problem is particularly difficult because of the number of major fields which developed important potentials in 1938. Two-thirds of the fields mentioned could, for a while at least, supply the entire state market. Allocation of this continually developed new oil is a real problem. The fact that actual production at Wilmington is some 16,000 bbl. per day above the Umpire's quota is an indication of the problem. Yet actual production represents a different viewpoint as to what the field should produce, and when 8,000 bbl. wells are curtailed to less than four percent of potential to meet this viewpoint, it can scarcely be said that the field is not curtailed.

When the problem is viewed as a whole, such discrepancies become rather minor. It is an achievement that such a prolific town lot field as Wilmington can be controlled at all, and certainly the divergence of opinion and its results are not of a magnitude to call for any radical revision of the present proration methods. Judging from the experience of some of the eastern states, the California industry has benefited in no small measure in being free of the harassing mass of expensive litigation attendant on government control.

Total production of oil in 1938 was 249,749,246 bbl., a daily average of 684,244 bbl., an amount exceeded only by the production of 1923 and 1929. During 1938 approximately 920,851 bbl. of new daily initial production were developed. This was three times the amount developed in 1936, and exceeds any since 1929. Perhaps the 1938 new daily initial production is an all time high. That is, if the 1938 wells had been allowed to flow at maximum capacity or at open rates comparable to those often used in the past, it is probable that the new potential of 1938 would have exceeded all previous records.

In view of the outstanding new production record of 1938 it is not strange that the proration mechanism became strained.

Much discussion of overproduction took place, particularly in the latter half of the year, and by December the idea was finally accepted that the situation was to be taken seriously. Agreement was reached, and production was cut from 669,000 bbl. per day on December 18th to 619,000 bbl. on December 26th. Fluctuations occurred in January, 1939, since many operators customarily produce more during the first half of the month. However, production declined to 606,856 bbls. by January 27th—only 1,741 bbl. above the allotment of 605,115 bbl.

Two points are strikingly brought out by the proration condition: (1) It is note worthy that order and stable price structure prevailed at all considering the development of practically an all time high of new initial production, the greatest actual production in nine years, town lot development in older fields—particularly Torrance and Montebello, and large scale town lot development at Wilmington. Furthermore, the state potential from all fields reached an all time high of more than 1,900,000 bbl. per day during 1938, and the same year coincided with the general business low of Depression II which reached bottom in May-June. A system capable of weathering these conditions can't have serious defects, and it is of note that no price cuts took place in California. (2.) Conditions comparable to the above have only existed two or three times in the last 30 years, and the recent discovery rate is unusual. Consequently present difficulties are apt to appear minor in perspective.

The last few days of December, 1938, and following weeks in 1939 have illustrated the possibilities of voluntary control. The problem had gotten beyond control of the usual control machinery, due to the burden of new potential discovered, so special meetings were called by the Independent Oil Producers Agency, San Joaquin Valley Oil Producers Association, and Oil Producers Agency of California. These meetings resulted in formation of three committees: an emergency executive committee headed by E. E. Pyles, a fact-finding committee or "Grand Jury," and a landowners committee. Direct result of this effort was curtailment of more than 50,000 bbl. per day within ten days. November production before the committees were formed averaged 662,800 bbl. per day. Efforts in the last part of December brought that month's average down to 646,283 bbl., and the January, 1939 average dropped to 624,102 bbl., with production down to 586,900 bbl. on January 31st.

There has been some tendency on the part of many smaller operators to realize that production engineers may know something after all. Laboratory equipment is universally available now since repeal. An oilfield is essentially a big siphon bottle. It is obvious that if the gas escapes from the siphon without carrying fluid up through the tube with it, the problem of extracting the fluid will be much more difficult. More widespread recognition of this simple principle is perhaps making things easier for those administering curtailment.

NUMBER OF WELLS

More than 911 wells have been drilled in the course of developing the fields herein discussed. Proration by reducing the immediate operating income per dollar invested in wells has made drilling requirements take on an aspect that is gradually becoming more serious. California has not felt the influence of excess wells to the extent that it has been felt in Texas, but the per well daily production proportion has already reached a figure low enough to make the operation of many wells unprofitable. The allowable currently being produced by many wells in the state is higher than the direct allocation should be because many wells cannot be commercially produced on today's market and have been shut in. The shutting in of wells during periods of unfavorable market as the result of their inability to meet competition, as a rule does not adversely affect the quality of a well and many such wells, upon being reopened after shut-in periods of years, have shown improved rather than damaged productivity.

In oilfields where ownerships and leases involve small portions of land, excess wells are inevitable. The objection that the law of capture compels operators to drill many more wells than they desire seems to have a rather natural solution as regards the newly discovered fields in California. Operators who do not wish to drill closely spaced wells solve the problem simply by merely failing to take leases in such areas. It is obvious from an ownership map at the time a lease is taken that if a number of small tracts exist, there will probably be a well drilled on each tract. This information is available to anyone and small tract leases are ordinarily taken by companies who have a use for the oil or do not object to close drilling for various reasons of their own. Close drilling cannot always be criticized as a business venture, since there are many places in California where upwards of $300,000 worth of oil has been extracted per acre from wells costing from $50,000 to $100,000 with well density closer than a well per acre. Long Beach, with an average production in excess of 500,000 bbl. per acre, is a case where acre drilling has been profitable notwithstanding the theoretical contention that the oil might have been obtained with fewer wells. Rarely has the California operator had to contend with close drilling by neighbors without knowing what his probelm would be at the time he took the original lease. Many California operators who prefer to hold properties in reserve do not jump into the rush and take small leases. This policy is apparent in the leasing methods of many operators. The inevitability of close drilling in the west end of Wilmington Field was apparent from a glance at a land map and it is a fact that a number of companies who dislike close drilling simply refused to take leases in the area.

One of the causes contributing to the drilling of excess wells, or rather to the uneconomic rate at which necessary wells are drilled, is the development principle embodied in the basic lease generally used. The customary lease requires that wells be drilled 90 days apart.

At the time this lease obligation became customary, a market was generally available for the oil, and oil sales provided the revenue for carrying on the continuous operation of drilling the property.

The relief under such a situation was embodied in the clause providing the drilling and production operations could be suspended when the price of oil was less than 75 c. per bbl. at the well. The presumption in these leases was that when the market price of crude oil was higher than 75 c. per bbl., there would be a market for the well capacity production. This relief clause in leases was based upon the principle that the law of supply and demand would govern the price of oil. Proration with its effect of arbitrarily stabilizing the price of oil and, at the same time, limiting the quantity of output, has rendered this old lease clause obsolete. The price of oil does not directly follow the law of supply and demand but is maintained through curtailed production. Operators under such leases are faced with a situation whereby the price of oil at the well may be above the lease price that affords shut-down relief and yet they may face a condition of curtailed production whereby the amount of oil saleable at such prices is not sufficient to afford an income for carrying on a sustained drilling program.

The assumption that sale of oil at a certain price will account for the disposition of capacity production from wells is no longer valid. This situation has been and is being remedied in numerous spot instances by amendments of lease providing for stipulated rental payments for the privilege of deferring drilling obligations incurred in original leases. In order to carry out the fundamental philosophy of lessor-lessee participation in production, a temporary solution to the problem of excess drilling requirements could be provided by a lease provision requiring monthly payments of reasonable sums as advanced royalty where drilling is deferred. If these monthly payments were applied as advanced royalty, the lessor-lessee participationship relation would not be unduly distorted and yet landowners would receive some consideration for having their property encumbered and, at the same time, curtailed for the purpose of creating future reserves. Some such arrangement is essential if California is to avoid excess well difficulties.

At the present time there are somewhat more than 18,000 oil wells in California. As of January 1st, 1938, there were 13,651 wells producing and 4,318 shut-in wells, or a total of 17,956 wells, and on the basis of the 1937 average daily production of 653,444 bbl. per day, the pro rata production per well was about 36 bbl. per day. Compared with the situation in Texas, where there were 77,565 producing oil wells on January 1st, 1938, and new producing wells are being drilled at a rate of more than 10,000 wells per year, California enjoys a favored position. The pro rata per well production in Texas, in order to meet that state's market demand, is less than 15 bbl. per day per well. The 1938 development did not lower the California per well index.

Effect of New Drilling and Changing Demand on the Individual Well

Year	Annual Product. (bbl.)	Daily Av. (bbl.)	No. Wells	Av. per Well (bbl. day)
1933	173,083,319	474,201	15,689*	32
1934	175,508,566	480,845	16,056*	32
1935	207,832,131	569,404	16,463*	35
1936	214,773,315	586,730	16,932*	35
1937	237,196,568	653,444	17,956*	36
1938	249,749,246	684,244	18,699	36

*Figures by V. H. Wilhelm as published annually in Transactions, Amer. Inst. of Mining and Met. Engineers, Petroleum Division.

Increasing number of wells after 1935 indicates increasing excess of new producers over abandonments due to development activity and new discoveries.

Although considerably more than 25,000 producing oil wells have been drilled in California, abandonment of producers has kept the number of existing wells to the figures given.

Oil Wells Completed in California

1929	910
1930	755
1931	246
1932	184
1933	248
1934	449
1935	710
1936	786
1937	1,156*
1938	995
Total New Wells	6,439
Producers Abandoned, 1929-39	2,232
Net Increase	4,207

*All time high.

Some of the new fields discussed are being developed on a one well to 20 acres program and others are being developed on a one well to 10 acres program.

Development of the new fields should require approximately 2,000 wells, of which about half have been drilled. This is not a true picture of the state of development as approximately 725 are in Wilmington and Santa Maria Valley.

Full development of the new fields will not bring about a low pro rata well production quota approaching that of Texas. Yet even with this assurance, it is apparent that the present rate at which new producers are being drilled will decrease the 36 bbl. per well index. A decrease in demand would accentuate the seriousness. The solution of the excess well problem in California cannot follow the definite acreage restriction basis which has been adopted in New Mexico and adjacent states. Peculiarities of California structural geology and stratigraphy make such determinations impossible in too many places to permit compulsory restriction.*

Principles governing well reduction in California must contain an element of mobility by which errors in determination of per acre production can be readily adjusted from time to time. Advance royalty payments cover this situation to a certain extent in that such payments would be credited against the ultimate lease total to be absorbed rapidly or slowly, depending upon the type of production that might actually be developed. Such arrangements have been made in a few cases in exchange for relief from drilling obligations. At the present time some landowners with no wells are receiving more monthly oil lease income than other landowners with good wells.

Santa Maria Valley Field is an example of the excess well problem. There are 137 producing wells in the field but the field's allowable of about 19,180 bbl. per day could be produced from fewer than half-a-dozen wells. There is no present need for at least a hundred of the wells for any purpose except to conform with a theoretical and somewhat obsolete method of distribution of equities; 100 oil wells averaging in cost about $50,000 apiece seem an exceedingly expensive method of bringing about this distribution. However, at least 95 percent of the wells would ultimately have been necessary, and the problem is not one of wasted investment, but of frozen capital.

Another troublesome circumstance is the customary lease clause that drilling and production operations may be suspended when the price of oil is less than 75c per bbl. It is irrational that drilling and production operations should be lumped together in the relief provision. It is often economically possible to produce existing wells at a given price, and yet it is uneconomic to drill additional wells under the same market condition. It is a fallacy that the same relief should be extended to a drilling operation involving an expenditure of $150 to $300 per day that is extended to a production operation which may involve as little expenditure as $200 per month. One solution to this problem has been a lease clause permitting cessation of drilling operations when the price of oil drops to a figure substantially higher than the price at which producing operations may be shut down. This allows the operator to make a production profit and provides some income to the landowner without requiring a thoroughly uneconomic drilling campaign.

WELL SPACING

In all but two of the fields discussed, well spacing programs will call for an ultimate well density of one well to 10 or 20 acres, as the case may be in different fields.

Santa Maria Valley Field has often been criticized for its violation of the 10 acre spacing program. The violations are in the Beacon area or so-called hot spot which, upon critical analysis, appears to be not so hot in comparison with densely drilled areas in the Los Angeles Basin. As a matter of fact, 10 acre spacing has been disregarded in less than 80 of the 6,000 acres.

Wide spacing patterns have been impossible at Wilmington, but an approximate well density in the west end was obviously indicated by ownership maps before any of the wells were drilled and the net effect has been merely to increase temporarily the per day production and to decrease the ultimate per well production. While this latter situation will decrease the revenue per dollar invested, there is no evidence that it will decrease the ultimate production.

The spacing problems in the new fields offer no appreciable difficulties. Few wells have been drilled or are being drilled that cannot be classed as necessary wells from an engineering standpoint. Yet drilling is being carried on at an uneconomic rate. Approximately $8,000,000 has been invested in Santa Maria Valley wells to develop more than 100,000 bbl. per day of oil, when the demand never exceeded the present demand of 10,000 to 15,000 bbl. per day. Yet almost all the wells would have ultimately been necessary in a properly engineered production program, so they cannot be considered excess or unnecessary.

There are no important spacing difficulties, but rather problems of arriving at the rate of drilling necessary wells on the agreed spacing grid. The futility of solving the problem by spacing laws is therefore apparent.

SUMMARY

Some 1,250,000,000 and perhaps 1,500,000,000 bbl. of oil have been indicated by new discoveries in the last three years. In terms of markets, 1,500,000,000 bbl. of oil represents six years supply. During the three year discovery period, approximately 750,000,000 bbl. were consumed. The net effect of the new discoveries at this date is that the state's reserve position has been improved to the extent of about three years as compared with its position when the discovery cycle started. Actually the reserve position has been further improved by deeper discoveries in old fields, and by extensions, neither of which have been considered here.

Although less than one-third of the new field acreage has been drilled, a potential of 901,438 bbl. per day had been developed by January 1st, 1939. Actual production from these fields was about 130,000 bbl. per day in January, 1939.

It is of outstanding significance that the most successful exploration campaign in many years has resulted in so few years' supply of petroleum. If the writer's three year figure is wrong and the fields mentioned shall ultimately yield five or ten years supply, the point is still significant. Important as the new discoveries are, a great amount of optimism is necessary to support the belief that the recent amazingly successful discovery rate can be sustained for any long and dependable period of time.

ACKNOWLEDGEMENT

The writer is indebted to many individuals in the California oil industry for much geological and statistical data; to operating companies; to J. R. Pemberton, Oil Umpire, and members of his staff; and to the American Petroleum Institute for cheerfully supplying figures.

*William W. Porter II, "Geological Limitations to Oil Law", Bulletin Amer. Assn. of Petrol. Geologists, May 1938.

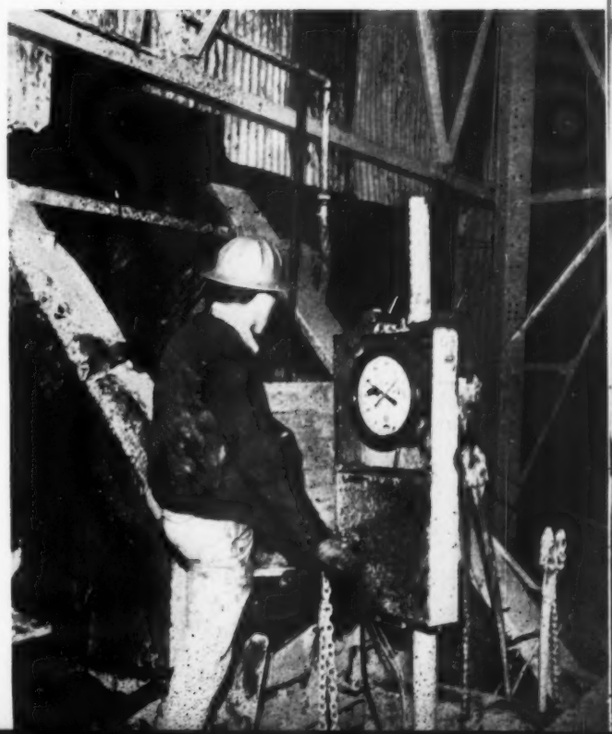
Drilling a Wildcat in California

The Hathaway Company prepares to sink a hole in promising territory in the West Montebello field. A cellar is dug at the site selected for the derrick and at the commencement of tower erection a gin pole is raised (above).

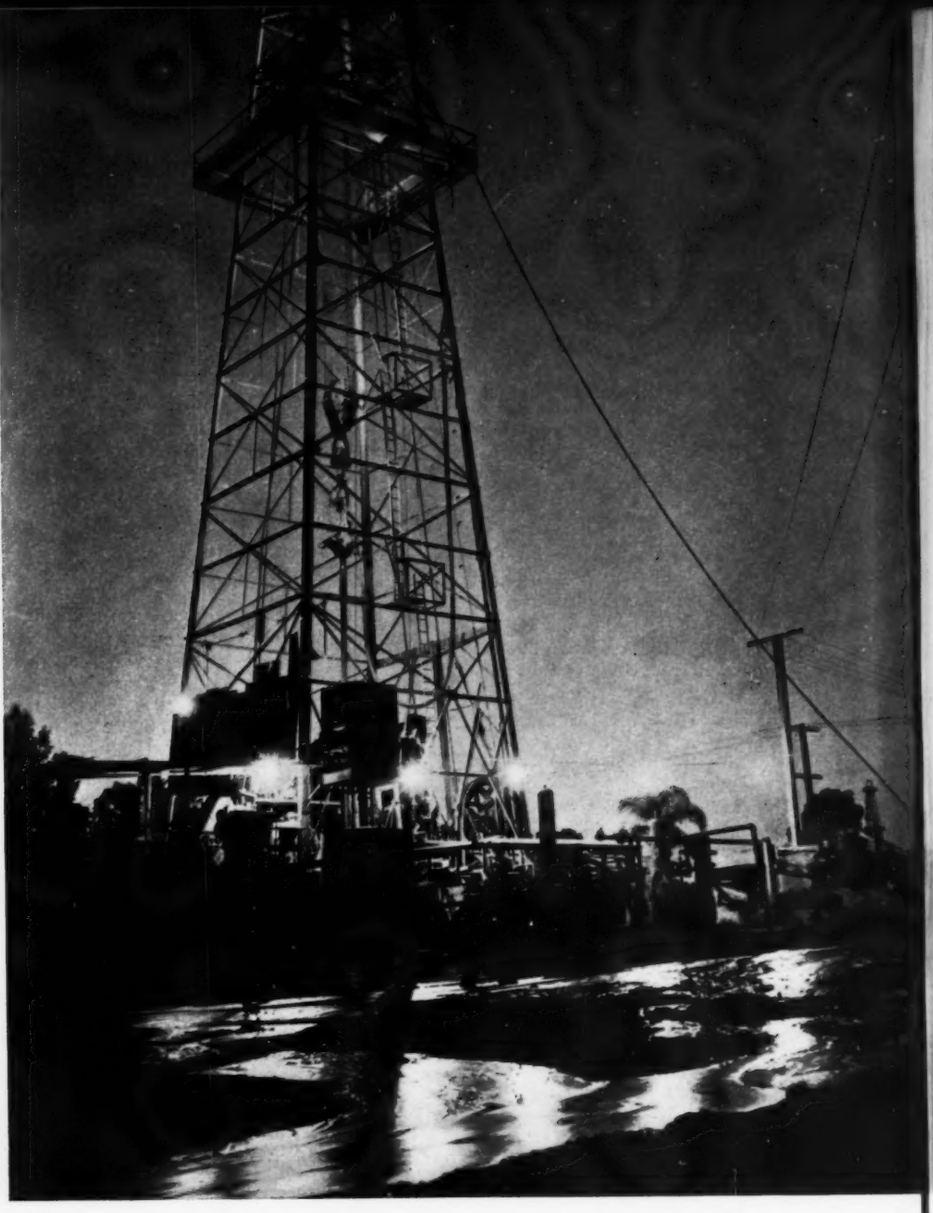
Pictured on the right is the unloading of drilling mud which has been brought ready mixed to the well site by tank truck. The lower right-hand picture shows the mud ditch before circulation was started.

Below—Erecting the boilers for the Frank J. Dore No. 1.

The pictures on this and the following three pages were taken by Orville Logan Snider—from Triangle Photo Service.



Upper left—The huge traveling block has a 300,000 lb. capacity. Center—Getting ready to spud-in. Upper right—Running surface pipe on the Frank J. Dore No. 1. Lower left—Guess-work is eliminated from modern drilling practice by accurate weight recording. Lower right—Pulling the string to change bits.



A good crew must have perfect timing and co-operation to handle the heavy tools at the high speeds of modern oil well drilling, and work is pushed through the night as well as the day. The derrick man goes into action stacking pipe, fully protected against a fall by his safety belt (upper left), while below men reach up for the elevators and links to pull the next stand. Lower left—The Kelley is made up onto the drill pipe. Right—A reamer is used with the rock bit to enlarge, straighten and smooth the hole before setting casing.

Core being removed from an inner core barrel on wire line coring. Right—Welding 14⅝ in. joints of surface pipe at the rate of one each four to five minutes. The crew was running seven joints per hour.

Below—Julian (Doc) Hathaway says "It's a great day!" when the Frank J. Dore No. 1 comes in for 200 bbl. daily in wildcat territory. When production falls off the well will be deepened in search of a deeper zone.

Fred Darcy and his wife watched the drilling of the Frank J. Dore No. 1 with no little interest and excitement, for they own four city blocks nearby and hope that this completion will mean that the West Montebello field will be extended toward their property.

WORLD PETROLEUM ABSTRACTS

Summaries of the Most Important Articles as Published in the Oil Press of the World Dealing With Technical and Economic Aspects of the Petroleum Industry. Edited by Dr. O. W. Willcox

GEOLOGY

Geology of the Bellevue Oilfield, Louisiana—A. F. Crider in BULLETIN AMERICAN ASSOCIATION PETROLEUM GEOLOGISTS, Vol. 22 (1938), No. 12, pp. 1658-1681.

The Bellevue oilfield is in the midst of the oil-and gas-producing area of northwestern Louisiana. Although the presence of a structure was long suspected from surface geology, the field was discovered in 1921 by a systematic plan of core drilling which located the crest of the uplift and proved it as an oilfield.

Geologically, Bellevue is probably a deep-seated salt dome in which salt has forced the overlying formations as much as 2,000 ft. above their normal horizontal position. The deepest well on the structure is Smith No. 2, completed at a depth of 6,147 ft. without encountering salt.

Bellevue is one of the outstanding shallow fields of northern Louisiana. The oil is produced from the Nacatoch sand at the shallow depth of 300-400 ft., with some gas and oil from the contact of the Upper and Lower Cretaceous at a depth of about 1,800 ft. The economy of drilling to such a shallow depth and the prolific nature of the Nacatoch sand has made Bellevue approach the Utopia of the oil man's dream. On January 1st, 1938, the field had produced a total of 9,860,430 bbl. of oil from 900 acres, or an average of 10,996 bbl. per acre, and for 1937, the field produced 280,130 bbl.

Depression conditions caused the field to be closed during 1932 and 1933. All wells were abandoned and casing was pulled from many of them. Production for the year previous to the shut-down was 103,930 bbl. and for 1937, with only a part of the field reworked, it had reached a total of 280,130 bbl. A re-drilling of one 80-acre tract, which was abandoned with casing pulled in 1932, to January 1st, 1938, resulted in a total new production of 3,000 bbl. per acre.

GEOPHYSICS

Geophysical Advancements Responsible for Illinois—Grady Triplett, in OIL WEEKLY, Vol. 91 (1938), No. 13, pp. 17-18.

Discovery of 17 oilfields in the Illinois Basin within two years is a triumph for geophysics. Although geophysical instruments claim full credit for only 10 of these fields, on the score of reserves the ratio is fully nine to one in their favor. This is due to the fact that the three larger fields, Centralia, Loudon and Salem, were thoroughly worked with geophysics before the first well was drilled. When it is realized that none of the trend plays would have been made without the early success of geophysics, it is not exaggeration to give this branch of science full credit for the whole southern Illinois development.

Since 1936 the Illinois Basin has had from 10 to 16 geophysical crews constantly at work over its area. In October of this year there were a dozen crews at work. The number of acres under lease in the basin has been as high as 7,000,000. There are no means of ascertaining what portion of these were taken on geophysical data but it runs well above half the total.

On the score of wildcat drilling, however, the use of scientific instruments is not in the lead. Of the 127 wildcats completed in 1937, 80 were drilled without the benefit of the seismograph, leaving 27 located after shooting, 17 from geologic survey information and three on a combination of seismograph and geologic data.

Only eight oil wells were completed from the 80 locations made without benefit of scientific exploration. There were 11 oil wells completed from the 47 located by scientific means. Reason for keeping so

75% SAVING
In COST of ERECTION
100% SALVAGABILITY
MAXIMUM EFFICIENCY
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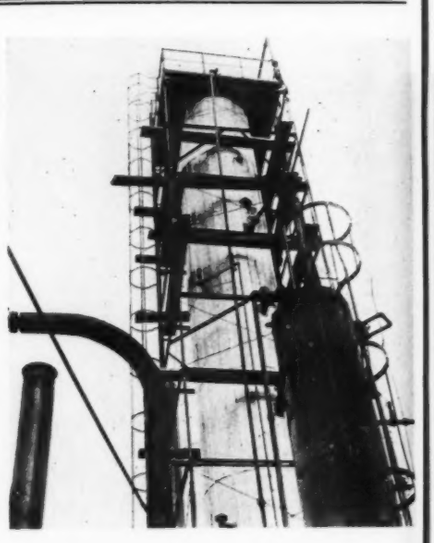
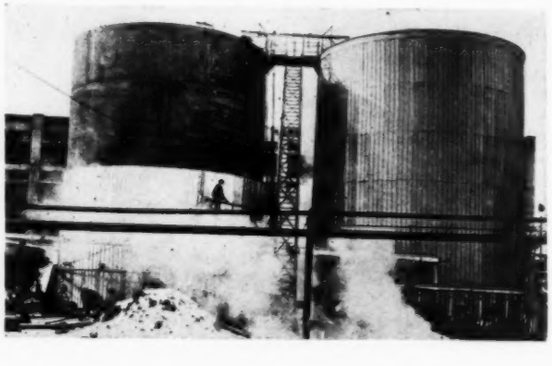


Removable Pre-Fabricated Panel Insulation



Shop fabricated metal panels approximately 3 ft. 6 in. wide and 8 ft. high are filled with the most efficient type of insulating materials to meet varying temperature conditions. The assembly forms a waterproof metal casing with any panel readily removable for inspection or repairs to the vessel.

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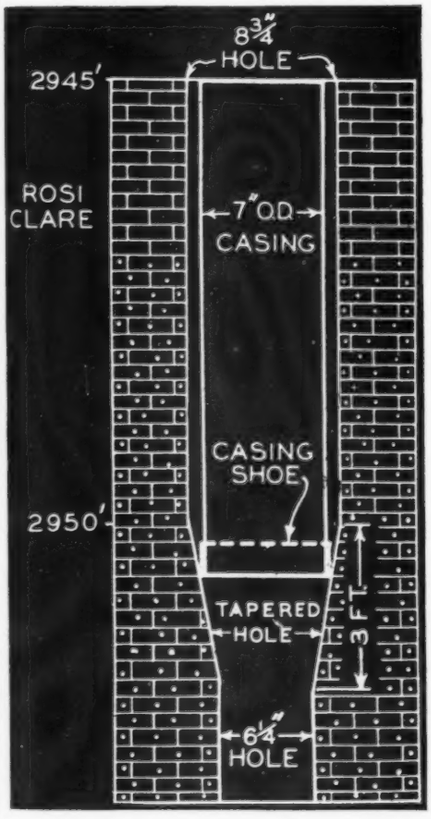
many crews busy in Illinois is the conviction that a basin as large as that covering the southern half of the state has more than two structures similar to Loudon, 18,000 acres, and Salem, 7,500 acres proven and likely to be enlarged to 8,500 acres when defined. These are the two major prizes out of reflection shooting in Illinois. Each has a reserve in excess of 100,000,000 bbl. Work already completed has left evidence to indicate at least eight structures on which no drilling has been done. No doubt there are others but the eight are known and it is likely that all will be tested by the drill in 1939.

DRILLING

Pure Oil Completes Illinois Wells Without Cement—Harry Simons, in OIL & GAS JOURNAL, Vol. 37 (1938), No. 28, pp. 56, 59.

The Pure Oil Company has improved on an old practice to the point where they are successfully running casings in the Illinois area without the use of cement behind the pipe. This has been accomplished by the use of a tapered seat (see illustration) which makes the landing of the string of pipe possible. The tapered hole is made with a special reamer.



After the pay is reached and it is decided to stop drilling, the pipe is laid down and the seven-inch O.D. casing run in the hole with a plain shoe on the bottom. The mud is preconditioned starting at 2,500 ft. and by the time the casing point is reached has a weight of 10.2 lb. per gal. and 40 viscosity. Heavying the mud aids in sealing off the producing formation immediately around the hole and prevents any considerable amount of fluid from traveling far through the lime. Conditioning of the mud also aids in the prevention of corrosion due to ground waters which frequently contain sulphur and sulphur compounds. Circulation is maintained until most of the cuttings in the hole have been removed and the pipe is then lowered on to the seat. The plain casing shoe fits solidly in the tapered hole with most of the weight of the pipe resting on it.

Of the 260 wells drilled by Pure in the central part of the Illinois basin, 225 were completed by this method. The other 35 were either dry holes or were producing wells that were cemented, one of the reasons being the passing of the point selected for a casing seat, the only recourse left being to cement the pipe. No failures where water subsequently started to come into the wells have been recorded on wells that were completed for good producers or did not require further acid treatment.

OPERATION

Returning Salt Water to Producing Formation in East Texas—H. H. King, in OIL WEEKLY, Vol. 91, No. 12, pp. 23-24, 25, 28.

The problem of disposing of salt water produced from the Woodbine reservoir of the East Texas field has been advanced toward solution by an experiment which showed that the water could be returned to a series of porous sands below the oil level.

The first attempt to return the water without allowing it to come into contact with the air proved unsuccessful on account of foreign matter clogging the walls of the return well. This was overcome by aerating the water to promote coagulation of foreign matter and filtering it off. Assuming that the capacity of the sand beds will eventually prove sufficient to hold all the salt walter produced, the cost of returning the water, while it will be large for the whole field, may be not more than ½ cent a bbl.

Cooperative Pressure-Maintenance Project in Billings Pool, Okla.—E. O. Bennett, in PETROLEUM ENGINEER, Vol. 10 (1938), No. 2, pp. 25-28.

Though owned by general companies, the Billings Pool is operated as a unit; one of the participating companies produces the oil and another operates the jointly owned high-pressure absorption gasoline plant.

The energy for flowing wells in the Billings pool is obtained partly from gas under pressure at the crest of the structure and partly from gas in solution, but mostly from water encroaching at the flank of production along the entire lower edge of the pool.

Realizing that the Billings pool should be classed as a water-drive pool, and that if properly controlled would yield a high ultimate recovery, Continental, Phillips-Shell, and Tidewater Oil Company engineers studied the possibilities of instituting a pressure-maintenance program.

A careful analysis and survey indicated that the return of 4,000,000 cu. ft. of gas per day, the total amount available from the gasoline plant in the pool, would retard the fingering-in of edge water and greatly reduce bottom-hole pressure decline. Water entering the edge of the structure along a uniform front was deemed to be very conducive to increased ultimate recovery.

After the geological and engineering surveys were completed a unit plan of operation was developed and placed in effect. The producing operations for the unit, which comprises the properties of the above-named companies, are being conducted by Phillips Petroleum Company.

From the inception of production the pool has been one of the most efficiently operated in the state of Oklahoma. The total pressure drop has been only 98 lb. during the production of a cumulative total of 3,998,192 bbl. gross. Approximately 40,800 bbl. has been produced per pound of pressure drop.

Return of gas to the producing formation in the Billings pool and production at a rate suitable to prevent the uneven encroachment of water will result in an ultimate recovery much larger than could be otherwise be obtained. The cost of producing the oil will be less than that for most similar pools on account of the extremely slow rate of dissipation of reservoir pressure, which will make pumping unnecessary, and because unit operation will reduce supervisory expense.

(NOTE: This is another instance going to show that common sense is spreading in the oil industry. It is being at last appreciated that every oil pool is a natural unit and should be approached as such. An earlier understanding of this simple fact would have saved the industry an enormous amouht of trouble with the old law of capture, and would have conserved millions of barrels of oil that have been lost. —ED.)

Report on A.P.I. Pump-Performance Experiment—M. G. Arthur, and E. K. Parks, before AMERICAN PETROLEUM INSTITUTE, Chicago Meeting, November, 1938.

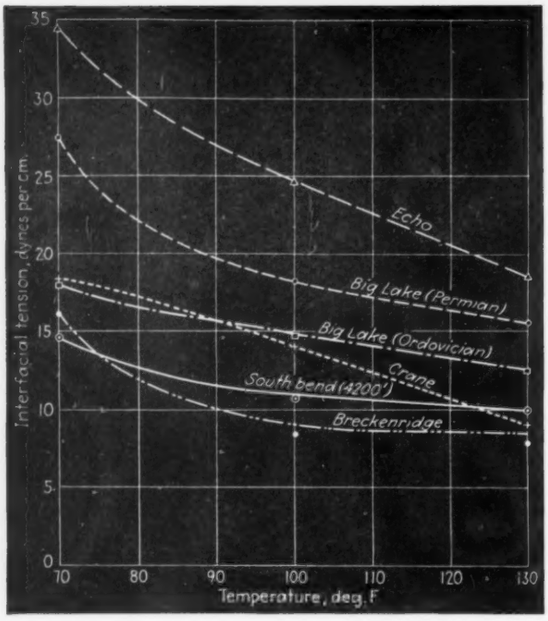
This paper describes the procedure and results of an American Petroleum Institute cooperative experiment on reciprocating-pump performance, conducted in an effort to show the influence on liquid pumped of such factors as: fluid head on the standing valve; viscosity; velocity through the standing valve; and, size of standing-valve opening, and size and length of any tubes leading to the standing valve.

The results of the test indicate that no serious loss of efficiency should be found in practice unless the proportions of sound design are disregarded (such as attempting to pump a large quantity of very viscous fluid with a relatively small pump at high speed, with low fluid head) and now it can be said safely that, provided the pumping mechanism is properly proportioned to the job, if low efficiency results, the cause lies elsewhere.

Nature and Importance of Surface Forces in Production of Petroleum—Frank C. Benner, Wesley W. Riches and F. E. Bartell, before AMERICAN PETROLEUM INSTITUTE, Chicago meeting, November, 1938.

Crude petroleum as it normally occurs is contained in the interstices and pore spaces of porous sand or limestone formations. These media vary considerably in the size of their openings, which may range from super-capillary pores and cracks down to capillaries of small dimensions. The nature and importance of the surface forces active in that class of reservoir in which the pore sizes fall within the range of capillary dimensions will be considered in this discussion.

One of the fundamental characteristics of capillary systems is the large surface area exposed per unit volume. As the capillary radius decreases, the area to volume ratio increases. According to calculations, a sand of 20-mesh grain size contains a total surface area of 1,500 sq. ft. per cu. ft. of sand; 100-mesh sand contains a total surface area of about 8,600 sq. ft. per cu. ft. of sand. These calculations give results of the correct order of magnitude, and it can be seen readily that the surface exposed in the porous media of which the oil reservoirs are composed can be of considerable magnitude. With such an enormous surface area exposed to the crude oil,



surface forces become a factor of importance in considering the production of petroleum from the reservoir. A knowledge of the surface forces active at the interfaces between sand, oil, gas, and water can be useful in predicting optimum rates of production and in determining the most efficient method of utilizing the energy of gas and hydrostatic pressures.

In reservoirs where the pore sizes fall within the range of small capillary dimensions, surface forces may be a controlling factor in the production of petroleum. It is essential that the surface properties of the oil, water, and sand in the reservoir be given consideration in determining the most efficient methods of production from the reservoir. Correlation of surface properties of reservoir sands and fluids, and a knowledge of the relative magnitude of surface forces operative in the reservoir, should enable producers to use more efficient methods of production and obtain a greater percentage of petroleum from the reservoir.

Phase Equilibria in High Pressure Condensate Wells—F. V. L. Patten and Denny C. Ivey, in OIL WEEKLY, Vol. 92 (1938), No. 1, pp. 20-22; 24, 26, 28, 30, 32.

This paper presents a technical study of the gas/oil ratios of what are known as condensate or distillate wells that yield a white or nearly white oil of relatively high A.P.I. gravity. There are numerous such wells in the Gulf Coast region and it is expected that more of this type will be found with deeper drilling. On account of the high gas/liquid ratio the operation of such wells calls for special care to prevent waste. The data shown in this paper is being considered by the Texas Railroad Commission as a possible basis for appropriate regulations. The problem has also an important legal phase, particularly as to what is meant by a gas well and when does a well produce oil.

From laboratory experiments with a pressure bomb and from observations on condensate wells it is concluded that in order to recover a liquid product from such wells it is necessary to operate them at not less than a certain minimum pressure. For instance, a well in the La Blanca field shows that operations at less than 3,800 lb. per sq. in. causes retrograde condensation in the reservoir, with corresponding failure to produce liquid. The losses which will result from failure to maintain pressure will vary from one field to another, and will depend on a number of factors, the most important of which are original reservoir pressure and original composition of the gas.

Factors Influencing the Application of Pumping Units—Emory Kemler, before AMERICAN PETROLEUM INSTITUTE, Chicago Meeting, November, 1938.

The application of pumping units on the basis of peak-torque requirements is the most satisfactory method available to date. Actual well tests included show that the use of maximum well load for figuring peak torque does not give representative results at higher speeds. The theoretical investigation of the effect of prime mover on peak torque shows that the engine coefficient of fluctuation should be the basis for correcting horsepower ratings, rather than the number of explosions per minute.

Besides the fact that gear units should be applied on the basis of peak torque, the data and theory presented in this paper show:

1. That the engine-drive service factors, as included in Table 3 and Fig. 1 of A.P.I. Standards No. 11-E, are not correct, and result in excessive penalties to proper-equipped single-cylinder engines.
2. That torsional vibrations can be set up in gear drives as used on pumping units, and must be given some consideration in future designs.
3. That the use of maximum load in figuring peak torque will give units larger than necessary if based on calculated loads at high speeds. At normal speeds the agreement is believed to be reasonable.
4. The Institute's Subcommittee for Rating of Speed Reducers should give further consideration to the above facts; and, as soon as sufficient data have been collected, revise the standards in accordance with the facts.

Flow of Oil-Water Mixtures Through Unconsolidated Sands—M. C. Leverrett in American Institute of Mining and Metallurgical Engineers Technical Publication No. 1001 (PETROLEUM TECHNOLOGY, November, 1938).

The behavior of mixtures of immiscible liquids in porous solids is of rapidly increasing interest to those engaged in the production of petroleum. The operation of artificial water-floods and the control of natural ones immediately raise questions concerning the fundamental nature of such processes. Moreover, it is now recognized that often water occurs dispersed throughout the rock from which the oil issues into the well, and thus tends to move toward the well simultaneously with the oil. The work reported here is a laboratory investigation of the simultaneous, steady-state flow of oil and water through the same column of unconsolidated sand. It is thus directly related to the situation in which water occurs in oil-producing sands; it may have less direct implications for the displacement of oil from sands by water.

From the results of the experimental work, it is concluded that the relative permeability of an unconsolidated sand to oil-water mixtures is substantially independent of the viscosity of either liquid, but is related to its pore size distribution, and to the displacement pressure, pressure gradient and water saturation that characterize the process. It is pointed out that the effects of these variables are in the direction to be predicted from a knowledge of the Jamin effect. It is concluded that the most probable mechanism of flow comprises segregation of most of the flowing oil in the larger channels between sand grains. Each such channel is believed to be substantially full of oil, except at very low oil saturations, when the oil probably moves as discrete droplets through the channels. In either case some oil is thought to be stationary within the sand. The water is believed to flow through the channels that are not occupied by oil, and, in the present case, as a continuous film around each sand grain.

It is proposed that, for a particular sand, the relative permeability to either phase is a function of the water saturation and the dimensionless group $\pi N/PD$ only, and it is shown that the data presented substantiate this view.

Surface and Interfacial Tensions of Oil-Water Systems in Texas Oil Sands—H. K. Livingston, in American Institute Mining and Metallurgical Engineers Technical Publication No. 1001 (PETROLEUM TECHNOLOGY, November, 1938).

Where an oil well produces both water and oil, the ratio of oil and water in practical operations becomes of great interest. The present paper shows that this ratio has some dependence on the character of the reservoir sand, particularly the size of the sand grains which influences the capillary phenomena in the producing horizon.

The normal range in size of sand grains in producing reservoirs in the Gulf Coast region, as determined by Halbouty, is chiefly between 0.012 and 0.0003 in. For ordinary porosities, the pore radius is one-fifth of the grain radius, so this indicates 0.0012 to 0.00003 in. as the radius of most pores in Gulf Coast reservoirs. In this size range, capillary phenomena have a decided influence on the state of fluids existing in the pores. For this reason, it seems unreasonable to attempt to study reservoir conditions scientifically without first knowing the extent of capillary effects in the petroleum, connate-water, reservoir-rock system. Some direct applications of this idea are pointed out.

Garrison has definitely stated the role of surface effects in the course of normal water encroachment. He concludes that the volumetric ratio of oil to water entering a well bore from a reservoir varies inversely as the interfacial tension cubed, other factors being constant.

As an example, this shows that a 13-dyne-per-centimeter system should produce from its reservoir one-eighth the water, except for effects of a small density change, that the *same* reservoir would yield if the system had an interfacial tension of 25 dynes per centimeter.

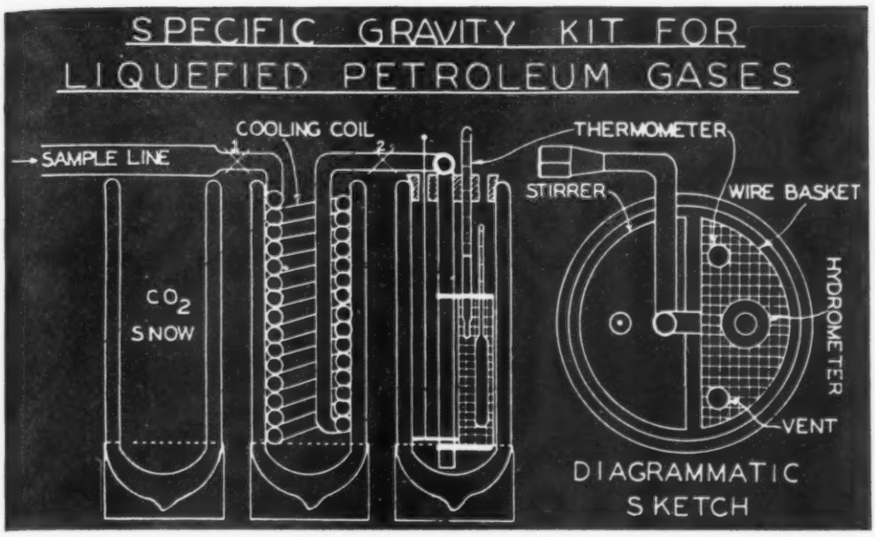
The accompanying diagram shows how interfacial oil-water tensions differ in oil reservoirs of Northwest Texas. Not much can be done to change conditions in the reservoir, but consideration of these relations will be useful in showing the oil production engineer where he stands in problems of water encroachment, water flooding, accidental water penetration and emulsions occurring in petroleum technology.

NATURAL GAS

Specific Gravity of Liquefied Petroleum Gases—W. M. Schanfelberger, in OIL WORLD, Vol. 31 (1938), No. 22, pp. 12-13, 15, 16.

This paper covers the development of a rapid method for the determination of the specific gravity of liquefied petroleum gases by the use of a hydrometer at low temperatures and at atmospheric pressure.

In the past, specific gravity determinations on liquefied petroleum gas stocks have been run by a bomb weighing method. This necessitated the service of a laboratory man and required from 30 to 60 min. A rapid method such as developed here is especially desirable when loading tank cars, since



the I.C.C. regulations specify that the maximum filling volume be based upon a representative gravity of the contents of the car. A gravity determination must therefore be made simultaneously with the final adjustment of the level in the tank car and it is impractical to hold up the loading crew for a lengthy laboratory test.

The apparatus is illustrated and a detailed procedure is given. The method is essentially the same as the standard A.S.T.M. gravity test by hydrometer. Samples must of course be cooled to a sufficiently low temperature to prevent weathering. Cooling is accomplished by passing the stock through a coil immersed in a propane bath in the case of butane stocks and in a CO_2 propane bath in the case of propane stocks. By substituting an unsilvered vacuum flask for the hydrometer jar, the temperature rise of the precooled stock is sufficiently retarded to permit accurate temperature and gravity readings.

The apparatus and method have been used with very satisfactory results by the natural gasoline department of the Standard Oil Company of California.

Natural Gas in 1937—F. S. Scott and G. R. Hopkins in MINERALS YEARBOOK for 1938.

The annual analysis of the natural gas industry by the Bureau of Mines shows that the strong upward trend in sales of natural gas, which began in 1934, was continued in 1937. The progress of the industry in recent years is illustrated by the fact that sales in 1937 exceeded the pre-depression maximum (1930) by 22 percent. Although the sharp decline in general business activity reduced the demand for gas for industrial use in November and December, domestic and commercial loads were well maintained throughout the year.

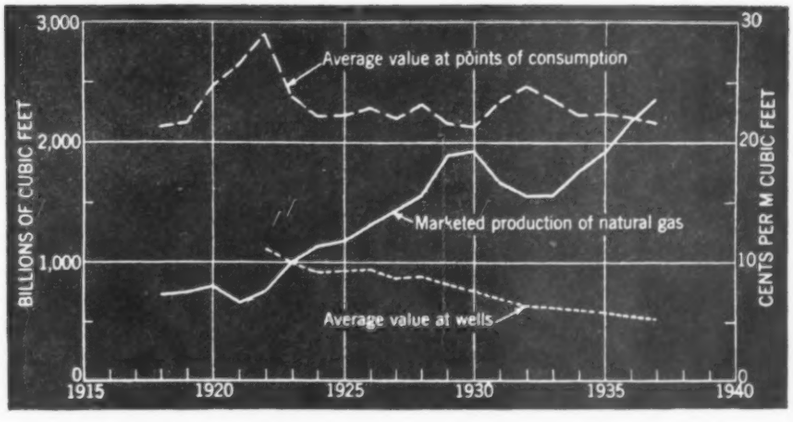
The five leading states in gas production maintained their positions, as each made a larger output; however, Texas, Louisiana, and West Virginia appear to have increased their relative importance. In 1937 these three states produced an estimated 56 percent of the total of the country compared with 54 percent in 1936.

Total marketed production in 1937 is estimated as 2,370,000,000,000 cu. ft., an increase of nine percent over the former peak of 1936. Texas is credited with more than 60 percent of the increase in production of the entire country, chiefly because of a great expansion in requirements for carbon-black manufacture and for drilling. Consumption of natural gas within the United States reached an estimated total of 2,362,300,000,000 cu. ft. in 1937, an increase of 9 percent over 1936 (See diagram below). This total is indicated by adding to marketed production imports of 289,000,000 cubic feet from Canada and subtracting estimated exports of 7,900,000,000 and 89,000,000 cubic feet to Mexico and Canada, respectively.

The value at the wells of gas produced in 1937 was approximately $125,610,000, an increase of five percent over that reported in 1936. The average price per thousand cubic feet at the wells fell from 5.5c. in 1936 to about 5.3c. in 1937. The value at points of consumption of gas used in the United States increased about seven percent to $511,002,000 compared with $475,439,000 in 1936. The indicated average sales value was 21.6c. per 21,000 cu. ft. compared with 22.0c. in 1936.

For the present, at least, proved reserves in most important producing districts are more than adequate and cause constant pressure for broader markets. This pressure has been somewhat relieved by increases in demand in recent years; nevertheless the average price at the wells has continued to decline.

The long-time decline in average value at wells is related chiefly to the migration of the center of the industry from the Eastern States, with their thousands of comparatively small wells, to the Southwest, with its wells of large capacity. The significance of this migration is illustrated by the growth in interstate movements from Texas and Louisiana to other States; between 1927 and 1936 such deliveries increased from 10,229,000,000 to 263,855,000,000 cu. ft., or nearly 2,500 percent.



Colloidal Properties of Iron Oxide in the Removal of Hydrogen Sulphide From Gas—Frank H. Dotterweich, and Wilbert J. Huff, before AMERICAN GAS ASSOCIATION, October, 1938.

An examination of published information on the rating of iron oxide purifying materials for the removal of hydrogen sulphide from gas discloses an unsatisfactory and inconclusive situation. The results obtained by chemical analyses do not form a basis for predicting the efficiency of oxide used and there is no standard test for this which has received universal acceptance. In general, the efficiency is determined by correlating various observations made while fouling the purifying material with hydrogen sulphide.

Various studies have recognized the significance of the capacity and activity of the iron oxide, but a clear cut differentiation of iron oxides based upon these properties has apparently not been attained and the properties are not entirely separable.

In this study, major attention was directed to a correlation of the physical and colloidal properties of the iron oxide with its efficiency in the removal of the hydrogen sulphide.

It was first necessary to develop a rapid means for determining the colloidal content of the oxide; this new method is described in detail. In applying this method, it appears that oxides high in colloidal ferric oxide and low in inert content give high activity, but when fouled with gas of high hydrogen sulphide concentration, the amorphous ferric oxide tends to go to the crystalline state. Mixing this type of oxide with greater proportions of shavings, although increasing the capacity, does not completely eliminate this undesirable feature due to the impossibility of uniformly dispersing solid colloidal over non-colloidal solid substances by simple mixing. This type of oxide, when mixed with equal proportions by weight of powdered Albany clay, high in aluminum content, gave a large increase in capacity. Although the study was not conclusive, it appears that a desirable oxide may be obtained when colloidal iron oxide and aluminum oxide are in the proportions by weight of two to one.

The test as developed for the determination of particle size or surface of iron oxide purifying material appears to give a satisfactory method of rating such material. It should only be used where the calcium content of the material is low. Materials with high concentrations of calcium should be washed before testing. This will tend to eliminate inconsistent dye absorption due to the calcium.

TRANSPORTATION

Soil Corrosion Survey by Electrolytic Test—I. A. Denison, in OIL & GAS JOURNAL, vol. 37 (1938), No. 19, pp. 96-98.

This paper is a summary of investigations made at the Bureau of Standards and relates to a method which might be used in deciding to what sections of a prospective pipeline coatings should be applied.

The idea is to map the soils along the right of way and collect samples at intervals of at least half a mile, taking soil from different depths; from these samples the most corrosive horizons are located in a preliminary survey.

The soil to be tested is placed in a corrosion cell between two electrodes of the same metal, the soil acting as the electrolyte. The cell is constructed in such a way that corrosion proceeds under conditions of moisture and aeration similar to those that prevail naturally in soils. The total polarization produced on the electrodes by an externally applied electromotive force is measured immeditely after opening the circuit and plotted against the current density on the anode. The average current density corresponding to a limited voltage range is taken as a measure of the corrosiveness of the soil.

The electrolytic measurements have been shown to be closely correlated with the loss in weight of a steel anode over a period of two weeks and also with the results of the long-time field tests of the corrosion of metals in soils which are being conducted by the National Bureau of Standards. The data obtained from these field tests consists of accurate measurements of loss of weight and depths of pits on five or six sets of 16 specimens each of wrought ferrous materials which have been removed biennially from each of 47 representative test sites located in various parts of the country.

An accurate record of leaks and replacements made on an extensive pipeline system provided an opportunity to correlate the results of the electrolytic test with corrosion experienced under actual operating conditions and hence to determine whether the test might be of value in making soil corrosive surveys. The electrolytic test was successful in measuring the corrosiveness of a large percentage of the soils along the right of way of a 128-mi. section of this pipeline system.

Transportation by Pipelines—Walter M. W. Splawn, in OIL & GAS JOURNAL, vol. 37 (1938), No. 9, pp. 53-55; 66.

The network of oil and gas pipelines now spread over the United States includes more than 96,000 mi. of interstate and more than 17,500 mi. of intrastate pipelines. During the past year these lines transported more than 1,215,000,000 bbl. of crude oil and 75,000,000 bbl. of gasoline in interstate commerce. The maximum capacity of the whole system is estimated at more than 5,000,000 bbl. in 24 hrs. The value (at refinery) of all crude oil and gasoline transported in interstate commerce last year is estimated at $1,682,000,000.

The average gathering line is approximately four inches in diameter, the average diameter of trunk lines is eight inches. The average cost of a mile of pipeline is approximately one tenth the cost of a mile of railroad.

The author, who is chairman of the Interstate Commerce Comission, says that in the future the I.C.C. will have to give more attention to oil pipelines because of the competitive struggle between various transportation agencies. In this respect the railroads have been the chief sufferers; in the base period 1923-25, of the total crude petroleum 8.3 percent was hauled by the railroads and in 1937 only 2.1 percent; and on this diminished share they have been compelled to lower their charges. At that, petroleum is still one of the most important classes of traffic for the railroads; in 1937 they collected $244,968,534 in freight charges on petroleum products. This may be compared with $223,471,450 collected from all shippers of livestock and all animal products, and from all grains and flour combined.

In 1937 annual reports were submitted to the I.C.C. by 59 pipeline companies showing the following—

Item—	1937	1936
Miles of line operated:		
Gathering lines	39,800	39,600
Trunk lines	56,811	54,460
Investment in carrier property	$802,945,910	$773,742,828
Operating revenues	$247,105,701	$219,057,109
Operating expenses	$ 99,641,086	$ 92,898,880
Pipe line taxes	$ 38,562,724	$ 31,667,436
Net income	$102,796,361	$ 91,741,892
Dividend appropriations	$ 75,839,332	$ 75,847,347
Oil transported (barrels):		
Originated	948,348,325	806,600,125
Received from connecting lines	340,071,608	295,116,780
No. of bbl.-miles (trunk lines):		
Crude oil (thousands)	279,212,919	(*)
Refined oil (thousands)	22,346,832	(*)
Employes:		
Average number	24,392	23,225
Compensation	$ 45,054,857	$ 38,248,175

*1936 barrel-miles not comparable with 1937.

Unitized Centrifugal Pipeline Pumps—H. W. Manley in OIL & GAS JOURNAL, Vol. 37 (1938), No. 19, pp. 91-93; 180-183.

The author describes the pumping equipment of the six-inch pipeline from Placedo to Corpus Christi, Tex., installed by the Barnsdall Oil Company. The character of the equipment was dictated by this circumstance: the potential of several new fields that were being developed in the area was unknown, and deliveries to the several pipeline stations would change with allowables and depletions. Hence, to reduce station construction costs, it was necessary to have a portable pipeline unit that could also be used as a permanent pumping station unit.

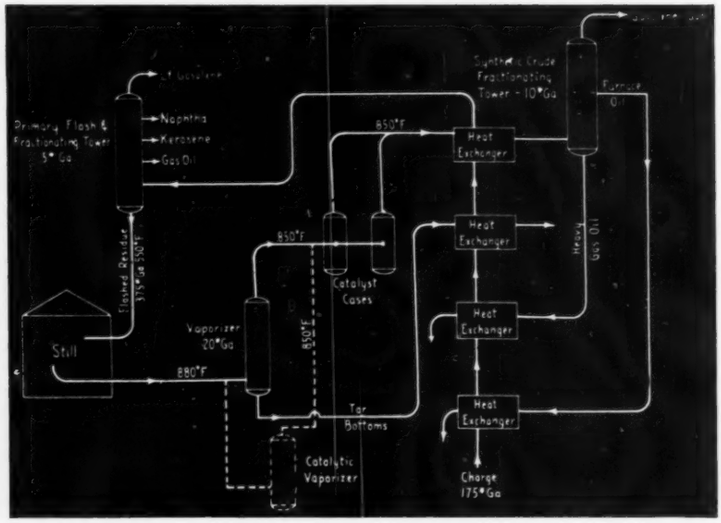
To meet these requirements three sizes of unitized centrifugal pumps rated at 3,600 r.p.m., driven by direct-connected, high-speed, multicylinder gas engines through 1:4 speed increasers were chosen, all parts being mounted on a common skid. The centrifugal pumps are four-stage with specially designed impellers to work against 600 lb. pressure.

A prominent distinction of these units is their small weight in comparison with comparable reciprocating units. The three centrifugal units employed on this line weigh from 10,000 to 17,000 lb. complete; corresponding reciprocating pumps weigh 25,000 to 65,000 lb. without accessory equipment; the weights per 1,000 bbl. daily capacity are respectively 700 to 1,000 lb. and 5,000 to 6,000 lb. In addition to highly desirable portability these unitized centrifugal pipeline pumps have shown low maintenance costs.

REFINING

Catalytic Processing of Petroleum Hydrocarbons by the Houdry Process—Eugene Houdry, Wilbur F. Burt, A. E. Pew, Jr., and W. A. Peters, Jr., before AMERICAN PETROLEUM INSTITUTE, Chicago Meeting, November, 1938.

The Houdry refining process, now in operation at several Socony-Vacuum and Sun Oil refineries is based on the use of silica-alumina catalysts which are of practically unlimited life and are particularly adapted to the production of aviation gasoline; in general it is said to give a yield of gasoline amounting to 45 percent from a single pass operation on any stock, whether gas oil or residue, and in any case the yield is higher than is usually obtained in a thermal unit. The process as a whole is represented by the accompanying schematic diagram.



The processes available under the Houdry patents are:

Catalytic cracking of a crude or any distillate fraction or residuum thereof, excepting straight-run gasoline, for the production of gasoline, gas oils, furnace oils, with or without the production of tar or heavy liquid products.

Catalytic viscosity breaking in liquid phase by which residues or tars may be reduced in viscosity to meet fuel specifications, without substantial production of gasoline.

Catalytic treatment of gasoline from catalytic or thermal cracking.

Liquid-phase catalytic treatment of aviation gasoline from catalytic cracking.

Catalytic de-sulphurization of gases from cracking or topping operations.

Catalytic polymerization in liquid phase of butenes.

Production of light-gravity gas oils for furnace-oil requirements or Diesel oils by catalytic cracking, charging heavier-gravity gas oils or residuums.

The authors believe that in these processes the industry has at its command a new and profitable

Great Pioneers

TEXAS 1836

March 6th, 1836, the Alamo, in which 183 defenders had taken refuge, fell with the slaughter of every man. It was Sam Houston who resumed active command of the army, after the death of General Fannin, and captured Santa Anna, the Mexican general. Standing alone, Texas faced many difficulties, but it was during this period that it won its independence from Mexico. In 1846, Texas added her own glorious star to Old Glory.

● TODAY, AS YESTERDAY, pioneers are first. As the dictionary puts it, they are men who "go before, preparing the way for others to follow." To this spirit of pioneering leadership the oil industry owes the development of the present Dowell chemical service for oil and gas wells.

Dowell did the seemingly impossible when, in 1932, it perfected and announced *Inhibited* Acidizing. During these past seven years, thousands of wells have been maintained at profitable production levels, due to Dowell—a tremendous gain to oil producers.

To its original service, Dowell has added numerous basic advances in materials and methods. Thus, its leadership in this vital field is constantly being extended through intensive research, modern technical equipment and a highly trained, experienced and permanent personnel.

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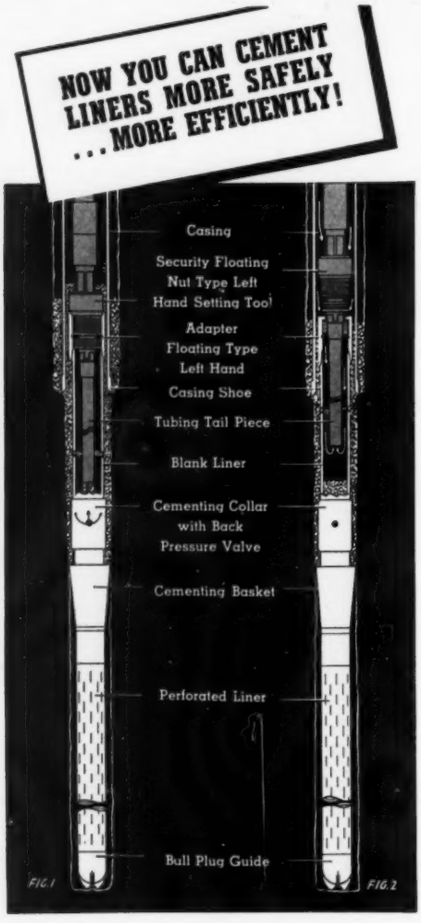

Although often desirable, the cementing of a liner in a well has generally been avoided because it incurred future removal difficulties. Ordinary steel liners, when cemented in place, can only be removed—if at all—after expensive fishing and cutting operations, which in themselves, might further jeopardize the well.

But "Securaloy," being completely drillable, entirely eliminates these dangers. "Securaloy" actually drills up faster than cement and liners made of this material can be quickly removed with an ordinary drilling bit when the time comes to recondition the well or explore for deeper zones. Furthermore, a full range of accessories, such as liner hangers, cement baskets, etc., is available made of "Securaloy" to permit *any* combination of cementing equipment *in completely drillable form.*

Thus, by using liners and accessories made of "Securaloy," operators are now obtaining all the advantages of cemented liners without the risks, and besides, *are fully protecting the producing life of their wells!*

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When cementing liners in place, the job can be done most efficiently with the new Security Left Hand Releasing Tool. A typical cementing job using this tool is illustrated above. The liner is run in the hole in the conventional manner and is cemented in place through ports placed above a baffle plate (fig. 1). After the cement is put away the tool is backed off, raised a short distance, and circulation is reversed to quickly wash all excess cement out of the liner and back up the run-in string (fig. 2).

The Left Hand Releasing Tool is particularly suitable for this cementing operation because it does not require packing or rubbers of any kind on the tail pipe to maintain high cementing pressures. In addition, its releasing action is positive and fool-proof!

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means to achieve a better economic balance between gasoline, urnace oil, fuel oil, and crude requirements; to meet the need for higher-octane gasoline, and at the same time to adjust refining operations to the seasonal variations in demand for the principal products, gasoline and heating oils. It appears obvious that the application of this process will assist the industry in meeting the ever-increasing demand for distillate products, and at the same time in conserving our crude-oil reserves. The ability of the process to refine economically any type of crude would appear to make available for use many crudes not now suitable for conventional refinery operations, and thus again to increase our reserves.

Desalting Crude Petroleum, A Review of the Literature—L. F. Christianson and Joseph W. Horne, in BUREAU OF MINES REPORT OF INVESTIGATIONS 3422, October, 1938.

The presence of salt in crude petroleum has been known for a long time and in recent years the percentage of chlorides of sodium, calcium and magnesium in some crude oils has increased to the point of creating a serious problem. Means of getting rid of these salts are therefore receiving increased attention.

In this publication the authors review the whole subject. Besides describing how corrosive salts affect petroleum equipment they outline all known physical and chemical processes and methods for removing salt from petroleum. In addition they discuss various demulsifying and other processes which with further study may prove useful in individual desalting problems. Petroleum technologists who have salt problems will do well to become familiar with this publication.

SUBSTITUTES

Manufacture of Hydrocarbon Oils from Industrial Gases by the Process of Synthetic Oils, Ltd.—W. W. Myddleton, in OEL UND KOHLE, Vol. 14 (1938), pp. 655-657; 673-676.

Using a water gas containing carbon monoxide and hydrogen in proportions varying between 1:1 and 1:5 under atmospheric pressure, and catalysts insensitive to sulphur poisoning, this process yields Diesel oils and unsaturated hydrocarbons suitable as starting material for the synthesis of lubricating oils. The first product of the reaction, or the primary oil, consists of olefins which are hydrogenated by passage over a catalyst along with hydrogen contained in residual gases from previous operations. The octane number of the product varies between 32 and 65, depending on the catalyst used and the composition of the original gas; cobalt catalysts give a lower degree of hydrogenation than nickel catalysts.

The present experimental installation has a capacity of 100 cu. ft. of gas per hr. The primary product is a mixture of gases and oil containing wax, which is electrically precipitated, leaving an oil boiling at about 98 deg. C. The yield of this oil is about 0.9 Imp. gal. from 1,000 cu. ft. of gas.

In comparison with other processes for the synthesis of hydrocarbons from mixtures of carbon monoxide and hydrogen, the described process is said to have several advantages.

Limiting the hydrogenation to the primary oil permits obtaining desirable products without cracking; the amount of secondary products suitable for conversion into lubricating and transformer oils is greatly increased; it is unnecessary to adhere to a fixed ratio of carbon monoxide to hydrogen in the original water gas; the catalysts employed are resistant to poisoning.

On the basis of results obtained in this experimental plant a larger pilot plant is in course of erection at Glasgow for treating up to 200,000 cu. ft. of gas a day.

GENERAL

Oil Search in Papua—Editorial, PETROLEUM TIMES, Vol. 40 (1938), No. 1035, p. 635.

The new ordinance to regulate prospecting and mining for petroleum in Papua is reviewed. Aside from the usual stipulations as to filing claims, paying fees, etc., it is provided that if oil is found in a recognizable field covered by properties under different ownership, it must be unit operated.

(NOTE: It does not seem possible to invent a neater method of burying the pernicious law of capture that has been and still largely is the bane of the American petroleum industry. Why has this simple expedient been so generally overlooked?—ED.).

Specific Refractivity and Carcinogenicity of Mineral Lubricating Oils—S. J. M. Auld, in JOURNAL INSTITUTION PETROLEUM TECHNOLOGISTS, Vol. 24 (1938), No. 180, pp. 577-583.

With the idea of enabling the textile industry to choose lubricating oils which should be substantially free from properties or constituents considered to contribute to the occupational disease of mule spinner's cancer, the Manchester Committee on Cancer has suggested an alleged relationship between carcinogenicity and the refractive index and specific gravity of the lubicating oil:—

> "Mule-spindle mineral lubricating oils should have a specific refractivity below 0.5539 when the specific gravity is above 0.895, or a specific refractivity below 0.5569 when the specific gravity is below 0.895. By specific gravity is meant the specific gravity at 60 deg. F. in relation to water at 60 deg. F. vacuo/vacuo. By specific refractivity is meant $\frac{d-1}{d}$, where n is the refractive index for d line sodium light, and where d is density in grams per millilitre at 20 deg. C."

In view of the importance of the subject the author made an investigation with the following conclusion:

1. Two oils from different sources, both of them meeting the Manchester Committee specification when used alone, may be mixed in some proportions and fail to meet the specification, whereas in other proportions they comply.
2. Two oils of different types, of which the naphthenic oil meets and the paraffinic oil does not meet the specification, may when mixed in some proportions comply with the specification, whereas in other proportions they will not.
3. Naphthenic oils increase in specific refractivity with increase in viscosity and increase in specific gravity. Paraffinic oils decrease in specific refractivity with increase in viscosity and increase in specific gravity.
4. Naphthenic type oils decrease in specific refractivity with increase in the extent of refinement. Paraffinic oils increase in specific refractivity with increase in the extent of refinement. If refining removes the impurities causing cancer, the specific refractivity for refined lubricating oils is not a good measure of carcinogenicity.
5. Similar results are likely to be obtainable with other oils of different origin.
6. The foregoing conclusions must apply equally to tests with oils on living animals involving measurements of change of refractive index.

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BETTER BE SAFE THAN SORRY — GUIBERSON

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Official Figures for Soviet Oil Operation

1938	Production bbl.	Daily Average bbl.	Run to Stills bbl.	Drilling feet
January	17,647,000	569,258	15,882,000	520,000
February	13,591,000	485,393	13,122,000	320,000
March	15,984,000	515,613	14,848,000	340,000
April	17,850,000	595,000	15,850,000	400,000
May	17,580,000	567,097	15,600,000	420,000
June	18,543,000	618,100	15,900,000	550,000
July	18,200,000	587,097	16,800,000	500,000
August	17,600,000	567,742	16,800,000	510,000
September	17,500,000	583,335	16,600,000	500,000
October	17,400,000	561,291	16,600,000	480,000
November	17,250,000	575,000	16,500,000	450,000
December	17,050,000	550,000	16,400,000	400,000
Total 1938	206,125,000	564,727	190,896,000	5,390,000
Total 1937	202,856,661	555,772	187,121,389	6,244,660
Total 1936	199,634,921	545,450	180,582,274	6,958,916
Quota 1938	244,215,000*	666,066	215,055,000	not available
Quota 1937	234,450,000	642,329	208,285,000	9,240,000
Quota 1936	222,345,000	607,000	182,250,000	7,100,000

*Crude oil and gas

SOVIET RUSSIA has lost her importance as a factor on the world oil markets—yet she could regain her former position readily if she would but go back to her original practice of retaining trained engineers from abroad and once more import the necessary equipment, which she herself is unable to produce.

Dwindling exports (particularly of gasoline, which dropped from more than 2,000,000 tons in 1932 to about 350,000 tons in 1937) have removed the menace of Soviet oil from international markets while Russia herself has become an importer of gasoline to her territory in the Far East. Increased home consumption is largely responsible for the decrease of exports and the reduced necessity for gold exchange to cover purchases abroad has made oil considerably less important as an export product. Soviet Russia is no longer forced to sell oil at any price and the low prices on the world market do not attract her when her own oil industry is facing difficulties to meet home consumption.

Soviet Oil Exports Jan.-Oct. 1937 and 1938

(Metric Tons)

	1938	1937
Crude Oil	141	68,438
Refined Products	842,948	1,412,467
Total Petroleum	843,089	1,480,905
Total Value (Rbl.)	68,700,000	110,970,000

Soviet Oil Exports 1931-1938

Year	Metric Tons
1931	5,212,000
1932	6,106,000
1933	4,890,000
1934	4,310,000
1935	3,353,000
1936	2,660,000
1937	1,930,000
1938 (estimated)	1,150,000

In 1939 the Soviet oil industry will celebrate the tenth anniversary of oilfield reconstruction. A decade ago large equipment orders were placed in the United States for drilling, production, and refining. In 1932 Soviet Russia ceased the importation of oil equipment from abroad and decided to manufacture all requirements by domestic means, needless to say, copying the designs of equipment already imported. That this was detrimental to Russia herself may be readily seen.

Between 1928 and 1932 Soviet crude oil production had increased from 12,000,000 tons to 23,000,000 tons, and exports likewise had risen from 2,700,000 tons to 6,106,000 tons. During the five years when it had purchased its equipment abroad the Soviet oil industry made great headway. When importation of up-to-date equipment from America ceased, the situation changed; although crude output increased from 23,000,000 to 30,000,000 tons during the period from 1933 to 1937, exports decreased to less than 2,000,000 tons. The Soviets progressed but little during the second Piatiletka, for their machine shops have neither the experience nor the ability to turn out equipment of the high standard required, while the designs followed are still for the most part those of 1932—since which time tremendous strides have been made in improving technique. Thus it is that while production is still increasing, it is doing so at a considerably retarded rate in comparison with either the Soviet domestic consumption or world oil output, and at the present rate it will not be long before Russia not only has no balance for export but will find it necessary to import oil for its European territories.

Considering the vast reconstruction problem that the Soviet oil industry faces in the forming of efficient drilling and refining apparatus alone it becomes apparent that it would be much less costly for it to bring

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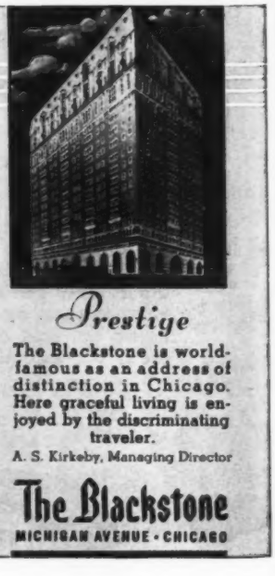
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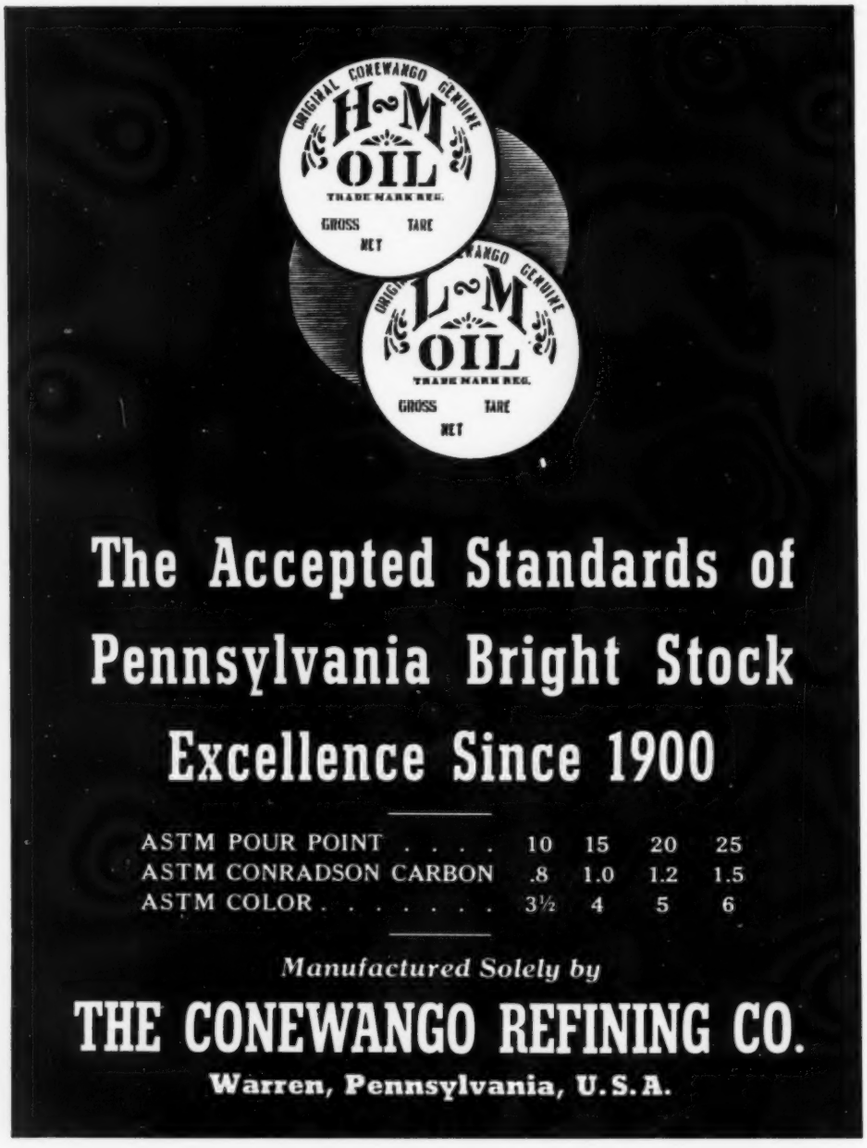

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itself up-to-date by placing large orders with the qualified equipment concerns abroad. The only alternative is to continue to tinker around with the more costly and less effective domestic machine shop.

The Soviet press emphasizes the importance of good operation more with regard to the co-ordination of the workers rather than to use of the machinery employed. While the former is indubitably a desirable feature, so is it desirable to have these workers know how to handle their tools and machinery. The Russian machine tool operators have much to learn before they become efficient at their job—why not engage technical assistance for supervising these workers as was done ten years ago? Those natives who were trained during the first Piatiletka have apparently been purged during the frequent liquidations of recent years and the personnel of today is not qualified for the work. Efficient instruction by experienced American petroleum engineers would be of considerable benefit to the Soviet oil industry and help it cope with the task set by the third Piatiletka. American manufacturers would probably be willing to help once again and would not be reluctant to extend credits to a stabilized Soviet oil industry as they did in former years. There are undoubtedly vast reserves of oil in the Soviet Union, but the industry in its present condition is not capable of producing and bringing it to the consuming centers in either the quality or quantity necessary.

The way to such a movement is open, and already the Soviet has broken the ice by ordering some drilling equipment in the United States for its Saghalin oilfields.

Oil in Cambrian Age

A SOVIET geological expedition prospecting for oil at Yakutia, in the Artic Circle, claims to have made a radical discovery. Several oil-bearing horizons giving small flows of 0.868 gravity oil have been located along the river Tolbi about 1,100 ft. deep in clay formations of what they report to be Cambrian age. The Cambrian is the earliest period of the Paleozoic era, and oil is known in the Paleozoic elsewhere only in regions of the United States such as Rocky Mountain district, in Alberta, and a little in Bolivia; Soviet oil deposits are invariably found in the Tertiary era. This is said to be the first discovery of oil in the Cambrian age anywhere in the world, although gas has been found in the Potsdam horizon in New York.

Transportation Problems

CONSIDERABLE difficulties are reported in Caspian-Volga oil transportation; November shipments were 350,000 tons in arrears. Volga barges were to carry some 250,000

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tons, but actually handled only 80,000 tons of oil. Ten oil barges arrived at Nikupol but could not be unloaded due to lack of storage facilities, while the railroad was unable to handle further shipments. There were also about 350,000 tons of oil on hand at Astrakhan ready for distribution to Stalingrad but no tank cars were available.

Reorganization and Recapitulation

THE SOVIET Commissariat for National Defense has been reorganized into independent Commissariats for Aviation (M. M. Kaganovitch), Armament (B. L. Vannikov), Supply of Munitions (I. P. Sergiev), and Shipbuilding (I. T. Tevosyan). The Commissariat for Soviet Heavy Industries, previously run by L. Kaganovitch, has likewise been subdivided, with Kaganovitch heading the Commissariat for Fuel. Others are: Chemical Industry, Building Materials, Electric Power, Ferrous Metals, and Non-Ferrous Metals. In subdividing administrative responsibilities it is expected to step up industrial production and productivity of labor.

A development which may indicate a strengthening of Russia's domestic affairs is the replacement of N. Yeshov as chief of the Interior Department and the G.P.U. by L. Beria, formerly of Baku, and the recall to their jobs of various men who were purged many months ago.

New Deep Well

A NEW RECORD for drilling depth by Soviets has been set at Karachukhur, in the Baku oilfield group. A well has been sunk to 11,458 ft. in the Podkirmakin layer, and is the deepest in Soviet Russia.

Relations with Japan

THE SOMEWHAT unfriendly relations between the Soviet Union and Japan with regard to the oil concessions on the island of Saghalin have been rather aggravated by the friction which has developed between the two governments with regard to fishing rights. The original contract expired several years ago and the Soviets will only renew for one-year periods instead of ten years.

Russia has excluded from the new grant of fishing rights the locations of Nogaevo, Itch, Bolsheretzk, and in the Japanese and Okhotsk Seas which the Soviet recently fortified for national defense. The Soviet has also contested the right of Japanese fortification of the Laperonese Straits as well as the militarization of the Chinese Eastern Railroad and protesting against the default of Y6,000,000 in payment for the railroad. How far these affairs will affect the annual renewal of the Japanese oil concession in Soviet Saghalin remains to be seen.

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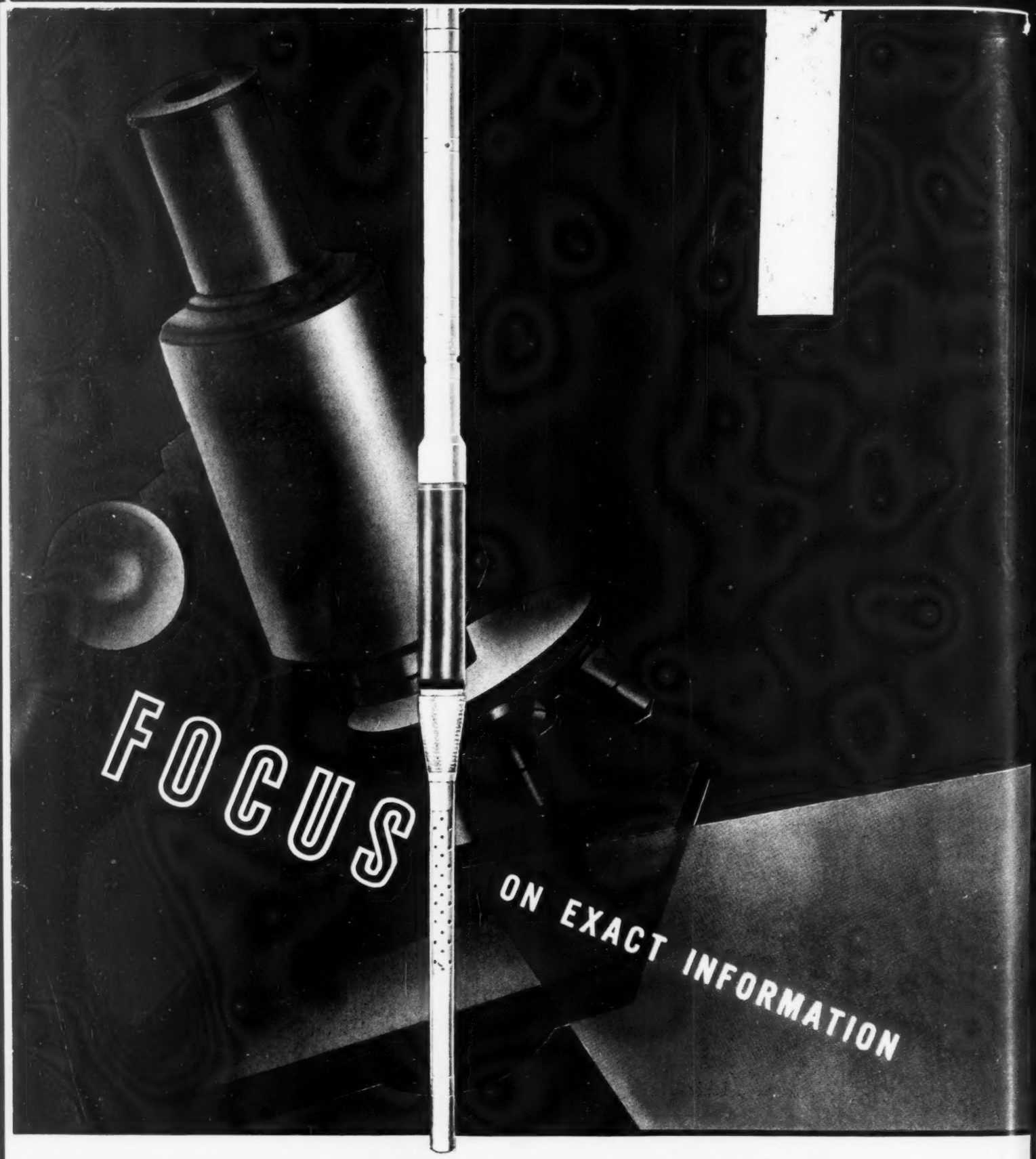
MARCH 1939



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OIL MAP

OF

COLOMBIA

MARCH 1939

Scale

MILES

0 5 10 15 20 25 50 75

KILOMETERS

0 5 10 15 20 25 50 75 100

LEGEND

- Capitals of Departments
- Capitals of Provinces
- Towns
- Departmental Boundaries
- International Boundaries
- Railroads
- Automobile Roads
- Aerial Cableways
- Pipe Lines & Pump Stations
- Air Routes
- Landing Fields
- Oil Fields

KEY

- TROPICAL OIL COMPANY / ANDIAN NATIONAL CORPORATION, LTD.
- SOCIEDAD NACIONAL DEL CARARE (50% Tropical Oil Company)
- COLOMBIAN PETROLEUM COMPANY / SOUTH AMERICAN GULF OIL COMPANY
- SOCONY-VACUUM OIL COMPANY DE COLOMBIA
- THE TEXAS PETROLEUM COMPANY
- SHELL OIL COMPANY OF COLOMBIA, LTD.
- "EL CONDOR" (CANADIAN EAGLE)
- RICHMOND PETROLEUM COMPANY OF COLOMBIA (Standard Oil Company of California)
- EQUATORIAL OIL COMPANY
- SINDICATO DE PETROLEOS "BOLIVAR"
- COMPAÑIA DE PETROLEO DEL CARARE

80° 78° 14° 12° 10° 8° 6°

Golfo de San Blas
Colon
PANAMA CANAL
Panamá
Golfo de Panamá
PEARL IS.
Golfo de San Miguel
R. Bayano
R. Chucunaque
R. Tuira
Golfo de Darien
R. Mulatos
Turbo
R. Atrato
R. Atrato
R. Morri
QUIBDO
Istmina
PACIFIC OCEAN
CARIBBEAN
PANAMA
CHOCO
ANTIOQUIA
FUERTE I.D
SAN

76° 74° 72°

CARIBBEAN SEA

Cartagena to New York 1865 miles
(Port Arthur, Texas to New York 1650 miles)

Cartagena to L'Havre 4285 miles
(Port Arthur, Texas, to L'Havre 4774 miles)

Coveñas to New York 1925 miles

Coveñas to L'Havre 4351 miles

SANTA MARTA

Pto. Colombia

BARRANQUILLA

Cienaga

ATLANTICO

Río Magdalena

CARTAGENA

Fundacion

R. Fundacion

Valencia

Canal del Dique

Calamar

ROSARIO

MAGDALENA

Venado

R. Cesar

Machiques

Tenerife

Plato

R. Chimiquica

R. Ariguani

Zambrano

SAN BERNARDO

El Carmen

Golfo de Morrosquillo

Coveñas

Pinto

Sta. Ana

R. Sta. Ana

Corozal

Lorica

Sincelejo

Magangue

Sincé

Mompos

Río Magdalena

Cga. de Zapatoza

Zapatoza

Banco

Retiro

Chinú

R. Cicuco

Loba

Brazo de

Talamalaque

Monteria

BOLIVAR

Gloria

El Carmen

Convencion

Gamarra

Ocaña

Bodega Central

La Cruz

Simiti

San Pedro

Gramalote

Ureña

Santiago

San Cristobal

Donjuana

Rubio

Bochalema

Cáceres

R. Nechi

Río Cauca

R. Porce

ANTIOQUIA

Remedios

Barranca Bermeja

Sogamoso

R. Lebrija

Pamplona

BUCARAMANGA

Piedecuesta

Zapatoca

San Andres

Málaga

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Jerico

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Rionegro

La Ceja

R. Nare

R. Samana

R. Minero

R. Horta

Vélez

Moniquira

Sonson

Chiquinquirá

TUNJA

Lago Tota

Sogamoso

Nunchia

La Dorada

Ramiriqui

Ubaté

Choconta

Guateque

Guatavita

Zipaquirá

Honda

Guaduas

Neira

MANIZALES

Mariquita

CALDAS

CUNDINAMARCA

BOYACA

SANTANDER

NORTE DE SANTANDER

Encontrados

R. Catatumbo

R. Zulia

R. Tarra

Escalante

PETROLEA FIELD

Villamizar

Colon

Est. Tachira

La Victoria

RIO DE ORO FIELD

Rio de Oro

R. De Oro

Pto Barco

R. Catatumbo

R. Socuavo del N

PIPE LINE TO COVEÑAS

N.

BARCO CONCESSION

SCALE
MILES 0 5 10 15 20
KILOMETERS 0 10 20 30

KEY
- Locations
- Drilling Wells
- Producing Wells
- Dry Holes
- Towns & Villages

78° 76°

ROLEUM

P

BIA

75

100

KEY

TROPICAL OIL COMPANY
ANDIAN NATIONAL CORPORATION, LTD.
SOCIEDAD NACIONAL DEL CARARE
(50% Tropical Oil Company)
COLOMBIAN PETROLEUM COMPANY
SOUTH AMERICAN GULF OIL COMPANY
SOCONY-VACUUM OIL COMPANY DE COLOMBIA
THE TEXAS PETROLEUM COMPANY
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(Port Arthur, Texas to New York 1650 miles)

Cartagena to L'Havre 4285 miles
(Port Arthur, Texas, to L'Havre 4774 miles)

Coveñas to New York 1925 miles

Coveñas to L'Havre 4351 miles

CARIBBEAN SEA

SANTA MARTA
Pto. Colombia
BARRANQUILLA
Cienaga
ATLANTICO
CARTAGENA
ROSARIO IS.
Canal del Dique
Río Magdalena
Fundacion
R. Fundación
Calamar
MAGDALENA
Tenerife
Plato
Zambrano
El Carmen
R. Chimiquica
R. Ariguani
SAN BERNARDO IS.
Golfo de Morrosquillo
Coveñas
FUERTE I.D
Corozal
Sincelejo
Lorica
Sincé
Magangue
Pinto
Sta. Ana
Mompos
Río Magdalena
R. Cicuco
Retiro
Chinú
Loba
Brazo de
Monteria
BOLIVAR
R. Sinú
R. San Jorge
R. Mulatos
Golfo de Darien
R. Chucunaque
R. Tuira
Turbo
R. Arrato
Simiti
Cáceres
R. Nechi
Río Cauca
R. Porce
ANTIOQUIA
Remedios
Barranca Bermeja
Río Magdalena
INFANTA
R. Murri
CHOCO
Pto. Berrio
SHELL CO. TEST
Anzá
MEDELLIN
R. Nare
Marinilla
Rionegro
La Ceja
R. Samana
R. Minero
QUIBDO
Sonson
CALDAS
La Dorada
SHELL CO. TEST
Honda
Neira
MANIZALES
Río Cauca
Mariquita
Guaduas
Zipaquirá
CUNDIN
Istmina

74°

72°

14°

12°

10°

8°

6°

RIO DE ORO FIELD

Rio de Oro

R. De Oro

Los Guayabones

Rio Catatumbo

Encontrados

Pto. Bacco

R. Catatumbo

R. Socuavo del Norte

NORTE DE SANTANDER

R. Socuavo del Sur

VENEZUELA

COLOMBIA

R. Zulia

La Paloma

R. Tarra

R. Catatumbo

R. Tibú

N.

CAMP 5

CAMP 4

CAMP 3

Pto. Reyes

PETROLEA FIELD

Petrolea

LANDING FIELD

R. Nuevo

CARBONERA No 1

Boca la Grita

R. Sardinata

Pto. Leon

Empalme

Pto. Villamizar

LEONCITO No 1

GONZALEZ No 1

R. La Grita

R. Guaramito

R. Pamplonita

Uracá

Tachira

San Faustino

La Victoria

Sardinata

PIPE LINE TO COVEÑAS

BARCO CONCESSION

SCALE

MILES 0 5 10 15 20

KILOMETERS 0 10 20 30

KEY

- Locations
- Drilling Wells
- Producing Wells
- Dry Holes
- Towns & Villages

Valencia

Venado

Machiques

R. Tocuyo

Carora

R. Misoa

Lake Maracaibo

San Lorenzo

R. Motatan

La Ceiba

Motatan

Trujillo

R. Sta. Ana

Zapatoza

Tamalamaque

RIO DE ORO FIELD

R. Catatumbo

Encontrados

San Carlos

Timotes

R. Tarra

R. Zulia

R. Escalante

El Vigia

R. Chama

Merida

Barinas

Gloria

El Carmen

Convencion

Gamarra

PETROLEA FIELD

Villamizar

Ocaña

Est. Tachira

La Cruz

Colon

San Pedro

Gramalote

CUCUTA

Ureña

Santiago

San Cristobal

R. Uribante

Donjuana

Rubio

Bochalema

Pamplona

R. Caparro

R. Suripa

R. Apure

R. Uribante

R. Nula

R. Sarare

Guasdualito

Sogamoso

R. Lebrija

BUCARAMANGA

Piedecuesta

Arauca

R. Arauca

Todos los Santos

Barrancabermeja

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Zapatoca

San Andres

Málaga

Pastora

R. Lipa

R. Ele

San Gil

Socorro

Cocuy

Soata

Charala

R. Casanare

Jerico

R. Horta

Vélez

Moniquira

Sogamoso

Chiquinquirá

TUNJA

Lago Tota

Nunchia

R. Guachiria

Ramiriqui

Ubate

Santiago

R. Guanapalo

Choconta

Guateque

Guatavita

R. Tomo

R. Bajagua

R. Cajaro

R. Bambu

R. Ariporo

SANTANDER

NORTE DE SANTANDER

BOYACA

ARAUCA

CASANARE

8°

6°

4°

2°

0°

80°

78°

P A C I F I C

O C E A N

C H O C O

A N D E S

V A L L E D E L C A U C A

N A R I Ñ O

P U T U M A Y O

E C U A D O R

R. Atrato

R. Murri

R. Andagueda

R. San Juan

Istmina

QUIBDO

Roldanillo

Tul

Buenaventura

Buga

Raposo

Palmira

CALI

Pradera

Naya

Zaragoza

R. Micay

Caloto

Santander

R. Cauca

Silvia

Guapi

R. Guapi

Iscuande

R. Iscuande

POPAYAN

R. Patia

Bolivar

Barbacoas

La Cruz

Sta. Rosa

La Union

R. Guiza

Sandona

PASTO

Tuquerres

Mocoa

R. Caqueta

R. Mira

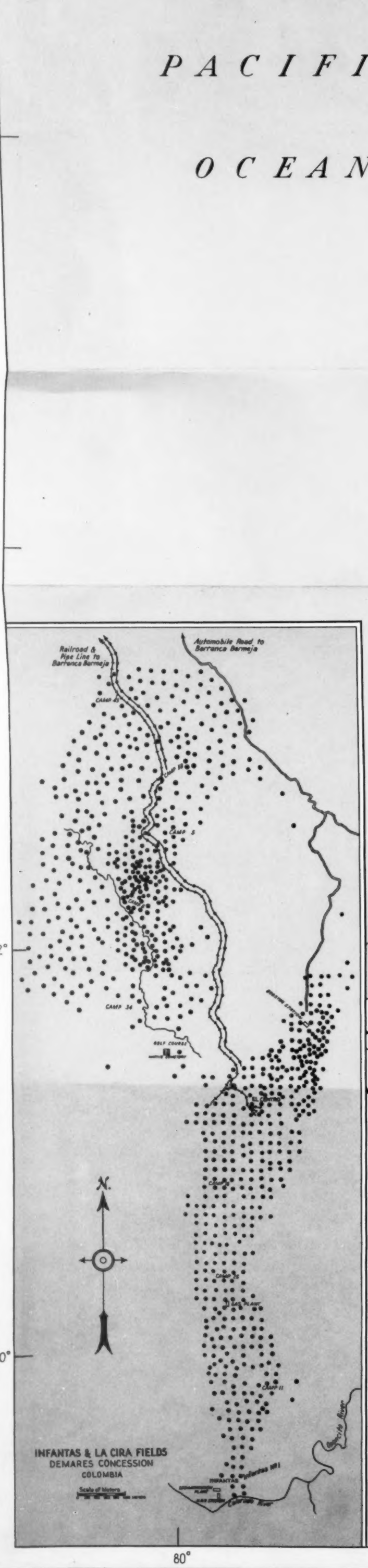
Ipiales

Tulcan

R. Guamues

R. San Miguel

R. Sucumbios



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Simiti
San Pedro
Gramalote
CUCUTA
Ureña
Santiago
San Cristobal
R. Uribante
Donjuana
Rubio
R. Cap
Bochalema
Cáceres
R. Nechi
Rio Cauca
Pamplona
R. Ul
R. Porce
R. Lebrija
R. Nula
Sogamoso
Remedios
Barrancabermeja
BUCARAMANGA
Piedecuesta
R. Arauca
Infantas
Llanos
Rio Magdalena
INFANTAS & LA CIRA FIELDS
Zapatoca
San Andres
Málaga
Pto. Berrio
Carare
San Gil
Socorro
SHELL CO. TEST
Cocuy
Anzá
R. Nare
Charala
Soata
MEDELLIN
Marinilla
Rionegro
R. Samaná
R. Horta
R. Casanare
Jerico
La Ceja
Vélez
R. Minero
Moniquira
Sonson
Chiquinquirá
Sogamoso
R. Negro
Nunchia
TUNJA
Lago Tota
La Dorada
Ramiriqui
SHELL CO. TEST
Ubaté
Neira
Honda
MANIZALES
Mariquita
Guaduas
Chocontá
Santiago
Zipaquirá
Guateque
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Pereira
Ambalema
Facatativá
Gachetá
Cartago
La Mesa
BOGOTA
IBAGUE
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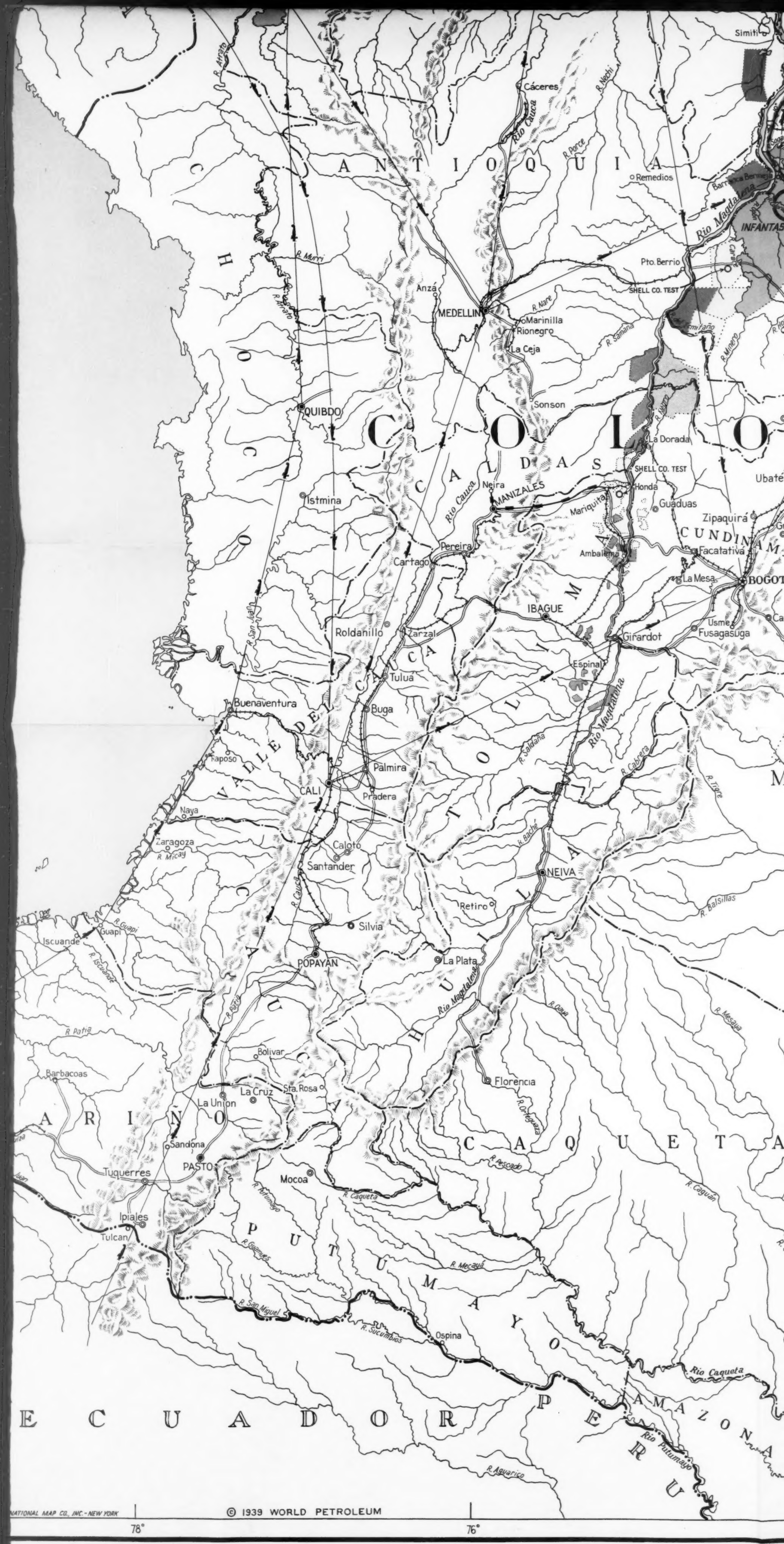
R. Mecayá
Ospina
Rio Caquetá
R. Aguarico
Rio Putumayo
76°
74°
72°

Q. Pariri
Caño de Paturia
Q. Mariposa
Q. Pescado
Q. Manzanares
Q. del Guamal
Lago Paturia o Paredes
Rio Paturia
Q. Macia
Q. de Melo
Q. Floresta
Q. Escocia
Q. de Leon
Q. Cristalina
Q. California
R. Sogamosito
Q. La Pradera
Q. Alemania o Perabosa
La Cristalina
Pradillo
La Pradera
Turin
NEW DEEP TEST LOCATION
Kilometer XX
Q. La Bonga
Horizonte
R. Yariguies
SOCONY-NARIÑO Nº1
Q. Guayabal
Q. La Ceiba
Rio Sogamoso
Q. Manguita
Q. Cayumbe
RESTREPO CONCESSION
Q. Raya
Q. Rayita
Brazo Pariguari
ISLA PARIGUARI
-SCALE-
MILES
KILOMETERS
-KEY-
Drilling Wells
Producing Wells
Dry Holes
Abandoned Wells



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78° 76°

San Pedro
Gramalote
CUCUTA
Ureña
Santiago
San Cristobal
R. Uribante
Donjuana
Rubio
Bochalema
R. Caparro
R. Suripa
R. Caparro
R. Apure
Pamplona
R. Uribante
R. Nula
Guasdualito
R. Sarare
R. Lebrija
Sogamoso
BUCARAMANGA
Piedecuesta
Arauca
R. Arauca
Todos los Santos
Zapatoca
San Andres
Pastora
R. Lipa
Málaga
R. Ele
San Gil
Socorro
A R A U C A
Cocuy
Soata
Charala
R. Casanare
R. Horta
Jerico
R. Casanare
Vélez
R. Ariporo
Moniquira
B O Y A C A
Sogamoso
Chiquinquirá
Nunchia
TUNJA
Lago Tota
M B I A
R. Guachiria
Ramiriqui
R. Guanapalo
Santiago
Chocontá
R. Cravo Sur
Guateque
Guatavita
Orocue
R. Tomo
Gachetá
Rio Meta
R. Muco
Caqueza
R. Vichada
Odune
Villavicencio
R. Meta
San Martin
R. Manacacias
R. Uva
M E T A
Q. Santos Gutierrez
Q. Pariri
Caño de Paturia
Rio Lebrija
Q. Mariposa
Q. Pescado
Q. Manzanares
Q. del Guamal
Lago Paturia o Paredes
Provincia
Rio Paturia
Rio Paturia
Q. Macia
Q. de Mieb
Q. Florecita
Q. Escocia
La Gomez
Sabana de Torres
Q. La Gomez
N.
Q. de León
Q. Cristalina
Q. California
R. Sogamosito
Q. La Pradera
Q. Afanador o Perabasa
La Cristalina
Pradillo
Q. Pavas del Lebrija
Turin
NEW DEEP TEST LOCATION
La Pradera
Q. Santos Gutierrez
Kilometer XX
Q. La Morena
R. Sogamosito
Horizonte
R. Cuemani
R. Yariguies
SOCONY-NARIÑO Nº1
Q. Cristalina
Q. La Morena
Q. Guayabal
Q. La Caiba
Q. Manzanita
Q. El Fundamento
Q. Cayumbe
Rio Sogamoso
Q. Cayumbe
Q. Oscuro
LA SALINAS FAULT
Q. Raya
Q. Rayita
Brazo Pariguari
ISLA PARIGUARI
RESTREPO CONCESSION
-SCALE-
MILES
KILOMETERS
-KEY-
Drilling Wells
Producing Wells
Dry Holes
Abandoned Wells
6°
4°
2°
0°
74°
72°